THE

Figure of the Earth,

Determined from

OBSERVATIONS

Made by ORDER of the

FRENCH KING,

AT THE

POLAR CIRCLE:

By Messrs. DE MAUPERTUIS, CAMUS, CLAIRAUT, LE MONNIER, Members of the Royal Academy of Sciences;

The Abbé OUTHIER, Correspondent of the ACADEMY;

AND

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Translated from the *French* of M. *de Maupertuis*.

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* Read in the Publick Meeting of the *Royal Academy of Sciences*, the 16th of *April*, N. S. 1738.

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The AUTHOR'S PREFACE.

THE great Attention of the Public to what ſhall be decided in the Queſtion concerning the Figure of the Earth, has not permitted me to delay printing this Treatiſe till it ſhould appear in the courſe of our annual *Memoirs*. As I intend to place the Whole of our Operation in the cleareſt Light that's poſſible, that every one may judge of its Accuracy, I have ſet down the Obſervations themſelves, juſt as they ſtood in the Regiſters of Meſſ^rs. *Clairaut*, *Camus*, *le Monnier*, *Outhier*,

thier, and my own, which all agreed with each other; without making the *Corrections* uſual in Works of this nature. Whoſe Authors, ſuppreſſing their Obſervations, have thought it ſufficient to give the Triangles *corrected*, and their Angles *reduced* to the juſt Sum of 180 Degrees; with the *Mean* of their Obſervations of the Amplitude of the Arc they meaſured. But the Method I have uſed will, I conceive, be the moſt ſatisfying to my Readers; as it enables them, from the Agreement or Differences of the Obſervations, to ſee how far they reach or fall ſhort of the Accuracy required. They may too, if they pleaſe, make Calculations of their own in a different Manner, and compare the Reſult with ours.

HERE

HERE it may not be improper to ſay ſomething of the Uſefulneſs of this Undertaking; which includes likewiſe the Voyage to *Peru*, begun before ours, and not yet finiſhed.

IT is well known of what different Opinions the Learned have been theſe 50 Years paſt, with relation to the Figure of the Earth; ſome holding it to be that of a *Spheroid* flatted towards the Poles; others that it is a Spheroid prominent in that Direction. This Queſtion, for its Curioſity only, might well merit the Conſideration of Philoſophers and Mathematicians: But the Advantages ariſing from the Diſcovery of the Earth's true Figure, go beyond mere Speculation; they are real, and of very great Importance.

WERE the Poſition of Places with reſpect to Longitude and Latitude ever ſo exactly marked on our Globes and Charts, it would ſignify little to the finding their true Diſtances, while we were ignorant of the length of the Degrees of the *Meridian* and of the *Parallels* to the *Equator*. And if the diſtances of Places are not very well known, to what dangers muſt the Ships be expoſed that are bound for them!

WHILE the Earth paſs'd for perfectly Spherical, it was enough to find the exact Length of any one Degree of a Meridian; this would give all the reſt: And the Degrees of the *Parallels* might be deduced by an eaſy Computation. Princes and Philoſophers had in all Ages been making Attempts this way. But the

Mea-

Meaſures of the Ancients were ſo inconſiſtent with one another, as to differ ſometimes by more than one half. And if to this we add the Uncertainty we are in as to the exact Length of their *Stadia* and *Miles*, we ſhall find that what they have left us upon this Subject is very little to be depended upon. In later times, Surveys were made, free indeed of the Inconvenience laſt mentioned, but which ſerved to almoſt as little purpoſe as thoſe of the Ancients. *Fernel*, *Snellius* and *Riccioli* have ſeverally given us the Length of a Degree of the *Meridian*; but when you compare them with each other, you will find Differences that riſe to 8000 Toiſes *Paris* Meaſure; that is, to about the ſeventh part of a Degree. And tho' *Fernel* happened to come neareſt the Truth, as

this could not be known, nor even preſumed from the Method in which he went to work, his Meaſure was as uſeleſs as the reſt.

WE muſt not however omit mentioning a *Survey* that was made in *England* in the Year 1635, becauſe it appears to have been done with great Care, and with proper Inſtruments. Mr. *Norwood* having in two different Years taken the Sun's Altitude at the Summer Solſtice at *London* and at *York*, with a Sextant of five foot Radius, found the difference of Latitude of theſe two Cities to be 2°. 28′. He then meaſured their Diſtance, and having taken into the Account all the turnings of the Road, with the Aſcents and Deſcents, reduced it to an Arc of the Meridian containing 9149 Chains. This compared with the Difference of Lati-

tude

tude gave him 3709 Chains to a Degree; that is, 367196 feet *Engliſh*, or 57300 of our Toiſes.

AN Order of LOUIS XIV. to the *Academy of Sciences*, ſoon produced a Work far ſurpaſſing whatever had been done of this kind. M. *Picard*, upon a Baſe exactly meaſured, and by a very few Triangles, determined the Length of the Arc of the Meridian between *Malvoiſine* and *Amiens* to be 78850 Toiſes: He obſerved, with a Sector of 10 foot Radius, that bore a Teleſcope of the ſame length, the difference of Latitude of theſe two Places, *viz.* 1°. 22′. 55″. And from thence concluded a Degree to contain 57060 Toiſes.

THE Method that Mr. *Picard* had uſed, with the many Precautions he had taken, were ſufficient Vouchers for his exactneſs. And the KING reſolved that the whole Arc of the Meridian through *France* ſhould be meaſured in the ſame manner. This Work Mr. *Caſſini* finiſhed in the Year 1718. He had divided the Meridian of *France* into two Arcs, which he meaſured ſeparately. The one from *Paris* to *Collioure* had given him 57097 Toiſes to a Degree; the other from *Paris* to *Dunkirk*, 56960; and the whole Arc from *Dunkirk* to *Collioure*, 57060; the ſame as Mr. *Picard*'s.

AT laſt Mr. *Muſſchenbroek*, jealous of the Glory of his Nation, to which himſelf ſo much contributes, having reſolved to correct the Errors of

of *Snellius*, both from his own Obſervations and from *Snellius* himſelf, found the Degree between *Alcmaer* and *Berg-op-ſom* to contain 29514 Perches, 2 foot, 3 inches *Rhinland* Meaſure, which he ſays is equal to 57033 Toiſes, 0 feet, 8 inches of *Paris*.

THESE laſt Surveys agreed ſo much better with each other than the former, that for the Climates they were made, we needed no better; nor indeed to find the Circumference of the whole Earth, provided it were Spherical, and had all its Degrees equal.

BUT why ſhould the Earth be a Sphere? In an Age when nothing leſs than the utmoſt Preciſion in all Science is inſiſted on, it was not to be ſuppoſed

ſuppoſed that the Proofs the Ancients had given of its ſpherical Form could paſs. Even the Reaſonings of the moſt celebrated Mathematicians, who gave it the Figure of a flat Spheroid, were not thought entirely ſatisfying; becauſe they ſeemed ſtill to be connected with ſome Hypotheſes, although theſe Hypotheſes were ſuch as one cannot well help admitting. As for the Obſervations made in *France*, they were as little thought ſufficient to give the Earth the Figure of a long Spheroid.

AT laſt the KING order'd the length of a Degree to be meaſured at the Equator and at the polar Circle, that the Compariſon of one of theſe Degrees with that in *France* might decide whether the Earth was long or flat; and that at the ſame time

time their Compariſon with each other might determine the Earth's Figure in the exacteſt manner.

IT is evident in general, that Sir *Iſaac Newton*'s Figure of a flat Spheroid, and Mr. *Caſſini*'s of a long one, will give very different Diſtances of Places that have the ſame Longitude and Latitude. And it is of ſome conſequence to Navigators, not to fancy they are ſailing upon one of theſe Spheroids, while they are really ſailing upon the other. The Miſtake would not be ſo conſiderable, if the Ship's Courſe lay all in the ſame Meridian. But for Places under the ſame Parallel, the difference of the Diſtances upon the one or the other Figure would be very great. In a Courſe of 100 Degrees Longitude, there might be a Miſtake of more than

than two Degrees, if ſailing really upon Sir *Iſaac Newton*'s Earth, one ſhould imagine himſelf to be upon Mr. *Caſſini*'s. And how many Ships have periſhed by ſmaller Miſtakes ?

THERE is this Conſideration further; That, till the Figure of the Earth is determined, there is no knowing how far theſe Errors may go. And in fact it appears from our Meaſures that ſuch a Miſtake will be ſtill greater than, from Sir *Iſaac*'s Table, it could be known to be.

I ſay nothing of the Miſtakes that muſt happen in oblique Courſes. It is needleſs to make any Eſtimate of them at preſent: Only it is plain enough that they would be ſo much the greater as the Courſe approached to a Paralleliſm with the Equator.

THE

THE Errors juſt now mentioned merit certainly our ſerious Attention: And if the Sailors are not at preſent ſenſible how advantageous it would be for them to know the true Figure of the Earth, it is owing rather to the Imperfection than to the Perfection of their Art. They are ſubject to a great many other Miſtakes in the Direction of their Courſe, their Diſtance run, and the like; amidſt which the Error ariſing from their Ignorance of the Earth's Figure lies confounded and hid. Yet it is ſtill a Source of Error more: And if ever (as it is to be hoped) the other Elements of Navigation are brought to Perfection, it will be ſeen of what Uſe the exact Determination of the Earth's Figure is.

THIS

THIS Determination would likewiſe be exceedingly uſeful in that important Problem, *To find the Parallax of the Moon*; which would greatly contribute to the compleating a Theory of this Satellite of our Earth; upon which the beſt Aſtronomers have always moſt reckoned for the diſcovery of the Longitudes at Sea.

AND to come to other Objects, lower indeed, but not the leſs uſeful, one may affirm that the Perfection of *Levelling* depends upon the Knowledge of the Earth's Figure. Such is the Chain that connects the Sciences, that the ſame Principles which ſerve to direct a Ship in her Courſe, and to trace the Moon in her Orbit, ſerve likewiſe to bring Water into a Fountain or Canal.

'TWAS,

'TWAS, no doubt, upon theſe Conſiderations that the KING order'd the two Voyages to *Peru* and to the *Polar Circle*. Near Views of particular Advantage have ſometimes produced great Enterprizes for the diſcovery of Countries, or of Paſſages to abridge certain Voyages; but the Determination of the Figure of the Earth is a general Benefit to all Nations and Ages.

THE Magnificence of every thing that regarded this Enterprize was equal to the Greatneſs of the Deſign. To the four Academicians, the Count de *Maurepas* added the Abbé *Outhier*, whoſe Capacity to aſſiſt in this Work was well known; He gave us Mr. *de Sommereux* for our Secretary, and Mr. *d' Herbelot* for

for *Deſigner*. If ſo many Hands were neceſſary for executing a Work of ſuch difficulty and in ſuch a Country, our Number would at the ſame time render our Operations the more authentic. And that nothing might be wanting in either of theſe reſpects, the KING conſented that M. *Celſius*, Profeſſor of Aſtronomy at *Upſal*, ſhould join us. Thus we left *France*, furniſhed with all that could be thought neceſſary to enſureSucceſs; and the Court of *Sweden* gave ſuch Orders, as procured us in its remoteſt Provinces all the Aſſiſtance imaginable. The Count of *Caſteia* then Ambaſſador in *Sweden*, ſollicited the Recommendations of that Court, with that Zeal he always ſhows in the KING'S Service; and if we have done any thing for the Sciences, that deſerves Acknowledgment, they will

pay

pay it to that Miniſter, to whoſe goodneſs we are ſo much indebted.

I thought it might not be diſagreeable to my Readers to prefix a ſhort Hiſtory of our Labours, which was read in the laſt publick Meeting of the Academy; and of which I have retrenched only ſome Reflections, that the detail of our Operations has now render'd ſuperfluous.

THE reſt of the Work is divided into three Books; becauſe it treats of very different Matters.

IN the firſt you have the whole Proceſs of our Operations for meaſuring an Arc of the Meridian that cuts the Polar Circle, and for aſſuring ourſelves that our Meaſures were juſt. It is divided into two Parts,

the one containing our firſt Operations; the ſecond the Repetition of theſe Operations, with Verifications of the Whole.

OUR ſcrupulous Exactneſs not only in the Calculations, but in the detail of all the Circumſtances of our Obſervations, may to ſome People ſeem to need an Apology. But in a Subject that has been ſo much diſputed, and is of ſuch importance, we thought we could not carry our Exactneſs too great a length. Mr. *Clairaut*, whoſe Skill in much more difficult Calculations is well known, was of great ſervice to us in theſe.

THE firſt Book concludes with a Problem which I had already publiſhed in the *Memoirs of the Academy* 1735, and which I have here inſerted,

ſerted, becauſe this is its proper place. It ſerves to determine the Magnitude and Figure of the Earth from the lengths of two Degrees of a Meridian; and by it, one may eaſily make a Table of the lengths of a Degree for every Latitude.

THE ſecond Book contains ſeveral Obſervations by which we determined the Elevation of the Pole at *Torneå* and *Kittis*; the quantity of the Refraction at the Polar Circle, and the Longitude of *Torneå*. We at the ſame time detect a received Error, which might not a little affect both Aſtronomy and Geography.

IN the Year 1695 *Charles* XI. King of *Sweden*, having ſent Meſſ^rs. *Spole* and *Bilberg* to *Torneå* to make ſome Aſtronomical Obſervations;

theſe two Mathematicians, with ſmall and imperfect Inſtruments, obſerved ſeveral Altitudes of the Sun at the Summer Solſtice, from which they concluded the Elevation of the Pole at *Torneå* to be 65°. 43′; while if they had employed the proper *Data* they ſhould have found it to be but 65°. 40′. even by their own Obſervations. Having thus determined the Elevation of the Pole, their Obſervations of the Sun's North Meridian Altitude gave them the Refractions at *Torneå* almoſt double to what they are in *France*.

IN all this there was a great deal of Error: The Town of *Torneå* is 11′ more to the North than they made it; And the Refractions are not there different from what they are at *Paris*.

FROM

FROM a great Number of Obſervations we found the Elevation of the Pole at *Torneå* to be 65°. 50′. 50″. And we have ſome reaſon to think there are few Towns in the moſt inhabited parts of *Europe*, whoſe Latitude is more exactly known. We have there oftner than once obſerved, at ſhort intervals of Time, and even in the ſame Day, the two Altitudes of the Pole-Star, which is there ſo elevated, that though one knew not the Refractions, or made no account of them, they are ſo inconſiderable that the obſerved Altitude might afterwards be ſafely uſed in meaſuring the Horizontal Refractions.

ON the other hand, in this Climate the Sun's Meridian Altitudes

in the Horizon furniſh many curious Obſervations upon the Subject of Refraction.

WE had likewiſe the Planet *Venus* for about two Months conſtantly above the Horizon, and could take her Meridian Altitudes both to the South and North.

AND from all theſe Obſervations made with the greateſt Care, we found that the Refraction at *Torneå* differed not from that in *France*: any difference we found was no more than what might ariſe from the Obſervations themſelves, or from Accidents wherewith the Refractions upon the Horizon may be affected.

IF

IF then the Refractions are found to be conſiderably leſs at the Equator than at *Paris*, and that they really increaſe from the Equator towards the Pole: This at leaſt is certain, that from *Paris* to the Polar Circle that Increaſe is imperceptible. And the Account which the *Hollanders* that wintered in *Nova Zembla* give of the Sun's appearing much ſooner upon the Horizon than he ought to have done in that Latitude, cannot ſhake what we had confirmed to us by ſo great a Number of Obſervations.

AS to the Longitude, *Jupiter*'s Situation in the Southern Signs kept him always hid in the Horizontal Vapours, at the times when we might have obſerved him. But we made

ſome other Obſervations to this purpoſe. One was of a Lunar Eclipſe in the Horizon; the reſt of Occultations of fix'd Stars by the Moon; from which we concluded with tolerable Certainty, that the difference between the Meridians of *Paris* and *Torneå* is 1h. 23′.

THESE Obſervations are chiefly owing to the Vigilance of Mr. *le Monnier* and Mr. *Celſius*; who in a Climate, where the Heavens are ſo coy to Obſervation, were continually attentive to ſeize every favourable Moment.

THE laſt Book contains our Experiments upon the Force of Gravitation in the Frigid Zone: A Subject which, beſides its general Importance

tance in Natural Philoſophy, is ſo cloſely connected with the Figure of the Earth, that Sir *Iſaac Newton* and Mr. *Huygens* thought, that from the different Weight of Bodies alone the Earth's Figure might be determined, and even more exactly than by an actual Menſuration of the Degrees. Upon the diſcovery of the Increaſe of Gravitation towards the Poles, they concluded, that to preſerve the ballance of the Parts that compoſe this Globe, and that the Seas might not overflow the Parts towards the Equator, the Earth muſt there riſe higher, and fall in towards the Poles. From the Increaſe of Gravitation as we found it at the Polar Circle, this Falling in muſt be ſtill greater than Sir *Iſaac* has made it. And ſome Experiments of our Academicians at the

the Equator, which are lately come to our hands, confirm the ſame Thing.

I conclude the Whole with a Problem ; To find the Direction of the primitive Gravity, or the Angles it makes with that of actual Gravitation ; which was the more proper in this place, as it comprehends the Reſult of all our Obſervations, both for the actual Menſuration of the Earth, and upon the Increaſe of Gravitation, and as from it may be deduced particular Solutions of a great many curious and uſeful Queſtions upon theſe two Subjects ; which are neceſſarily complicated with each other.

I have added a Map of all our Mountains and the Country adjoining; but the Poſition of thoſe Mountains only on which we made our Obſervations, is determined geometrically.

A

DISCOURSE

READ IN THE

PUBLICK MEETING

OF THE

Royal Academy of SCIENCES,

The 13th of *November*, N. S. 1737,

Upon the Meaſure of a Degree of the Meridian at the Polar Circle.

THE Motives and Purpoſe of our Journey to the North, I laid before this Aſſembly eighteen months ago: at preſent I am to give an account of its Execution, which it may not be improper to introduce by ſhortly reſuming what firſt gave riſe to this Undertaking.

IN

IN the Year 1672, M. *Richer* having obſerved, that at the Iſland of *Cayenne*, in the Neighbourhood of the Equator, Bodies weighed leſs than in *France*; this Diſcovery, with the ſeveral Conſequences that muſt follow from it, drew the attention of the Learned; and an illuſtrious Member of this Academy found that it equally proved the Motion of the Earth round its Axis, which did not much want any new Proof, and the Falling in of the Earth towards the Poles, which was then a Paradox. M. *Huygens* applying his new invented Theory of Centrifugal Forces to the Parts that compoſe the Terraqueous Globe, ſhewed, that if we conſider theſe parts as gravitating uniformly towards a Centre, and at the ſame time, revolving round an Axis, they muſt, to preſerve their mutual Ballance, take the Form of a *Spheroid flatted* towards the Poles. He went ſo far as even to determine the quantity of this *Flatneſs*; and all this from the common Principles of Gravitation.

SIR *Iſaac Newton* ſetting out from a different Theory, that of the univerſal Attraction of Matter, arrived however at the ſame

Con-

Concluſion with M. *Huygens*; only the quantity of this *Flatneſs* came out different in Sir *Iſaac*'s Calculation. In ſhort, one may venture to ſay, that if we examine the Figure of the Earth by the Laws of *Statics*, all the different Theories lead to the ſame Concluſion; whereas the Figure of an *oblong* or *oval Spheroid* cannot reſult but from *Hypotheſes* of *Gravitation* that are extremely forced and unnatural.

UPON the Eſtabliſhment of the *Academy of Sciences*, one of their firſt Reſearches had been, the juſt meaſure of a degree of the Terreſtrial Meridian. And this M. *Picard* had executed, for the Climate of *Paris*, with all the Exactneſs that could be deſired. But this Meaſure could be univerſally true, only upon the Suppoſition of the Earth's being perfectly ſpherical. If it was a flat Spheroid, it muſt be too great for the Degrees towards the Equator, and too little for thoſe towards the Pole.

THE whole Arc of the Meridian that paſſes through *France* was afterwards actually meaſured. But to our great ſurprize, the

the Degrees to the Northward came out ſhorter than the more Southerly, quite the reverſe of what was to be expected from the Figure aſſigned by Meſſrs. *Huygens* and *Newton*. According to this laſt Survey, the Earth muſt be prominent towards the Poles; and other Operations made upon the *Parallel* that paſſes through *France*, which ſeemed to be of great weight, confirmed the ſame thing.

THUS was the Academy divided in their Sentiments, and perplexed even by their own Enquiries, when the KING thought fit to ſignify his pleaſure, that the Queſtion ſhould be finally decided. A Queſtion not vainly ſpeculative, and fit only to exerciſe the idle and fruitleſs Subtilty of Philoſophers, but which might have a real influence upon *Aſtronomy* and *Navigation*.

TO give a proper Solution, it was neceſſary to compare two degrees of the Meridian, the moſt different in Latitude that was poſſible. For if theſe degrees increaſe or decreaſe from the Equator to the Pole, the ſmall difference between two neighbouring degrees, might mix itſelf with the Errors com-

committed in *Obſerving:* whereas if the degrees that are compared, lie at a greater diſtance from each other, this difference being repeated as often as there are intermediate degrees, muſt riſe to a Sum too conſiderable to eſcape Obſervation.

THE *Count de Maurepas*, a Lover and Patron of Learning, and who aims always at rendring it ſubſervient to the Good of the State, found the advantage of *Navigation* and that of the *Academy* equally concerned in this Undertaking. And the ſame view of publick Utility engaged the attention of the Cardinal *de Fleury*, whoſe Protection and Favour the Sciences enjoyed in the midſt of a War, in a higher degree than they durſt have hoped for in the moſt profound Peace. To the great joy of the Academy, an Order is preſently diſpatched from Court to determine the Controverſy concerning the Figure of the Earth; and, a certain number of its Members are immediately deputed to put it in execution.—So many were to go to meaſure the firſt Degree of the Meridian at the Equator; Theſe ſet out a whole Year before us. The reſt were commiſſioned Northward, to

meaſure the remoteſt Degree they could reach. And the ſame Alacrity, the ſame Zeal to ſerve their Country appeared in thoſe that were to endure the Rage of Equator Suns, and thoſe that were to freeze beneath the Polar Circle.

THE Company deſtined for the North was compoſed of four Academicians, Meſſ^rs *Clairaut*, *Camus*, *le Monnier*, and *Myſelf*; the *Abbé Outhier*, and M. *Celſius* the celebrated Profeſſor of Aſtronomy at *Upſal*, who aſſiſted at all our Operations, and whoſe Abilities and Advice were of ſingular uſe to us. If I might be allowed to do juſtice to the Courage and Talents of the reſt of my Companions, it would appear that the Work we were engaged in, difficult as it was, muſt become eaſy in ſuch Company and with ſuch Aſſiſtance.

THE Gentlemen that ſailed for the Equator we have no accounts of this great while paſt. Scarcely know we any thing more of them, than the difficulties they have had to ſtruggle with: and our own Experience has taught us to fear the worſt. For us, we have been more fortunate; and are ſafe

returned to preſent to the *Academy* the fruit of our Labours.

NO ſooner was the Veſſel that carried us over arrived at *Stockholm*, than we reſolved without loſs of time to ſet out for the Bottom of the Gulph of *Bothnia*, where we might judge which ſide of the Gulph was the moſt proper for our Operations, better than we could do by truſting to our *Charts*. Nothing could retard us, neither the frightful Stories they told us at *Stockholm*, nor the Goodneſs of his *Swediſh Majeſty*; who, notwithſtanding the Orders he had given in our behalf, told us oftner than once, that it was not without a ſenſible Concern he ſaw us purſue ſo deſperate an Undertaking. We arrived at *Torneå* time enough to ſee the Sun perform his Courſe for ſeveral days together without ſetting: a Sight that ſtrikes with wonder an Inhabitant of the Temperate Zones, even though he knows it is what muſt neceſſarily happen in that Climate.

HERE it may not be amiſs to give ſome Idea of our intended Work, and the Operations we had to go through, to meaſure a Degree of the Meridian.

EVERY body knows that as one advances towards the North, the Stars about the Equator appear lower, and thoſe towards the Pole more elevated. And 'tis probably this Appearance that gave the firſt Indication of the Earth's Roundneſs. This difference of the Altitudes of the ſame Star ſeen from the Extremities of an Arc of the Terreſtrial Meridian, I call the *Amplitude* of that Arc. This *Amplitude* is the Meaſure of the Curvature of the Arc; or, as it is commonly expreſt, it is the number of Minutes and Seconds that Arc contains.

IF the Earth was perfectly ſpherical, the Amplitude, or difference of the Meridional Altitudes of the ſame Star, would be always proportional to the length of its correſpondent Arc in the Terreſtrial Meridian. Thus, if, in the Climate of *Paris*, a diſtance of 57000 Toiſes upon the Terreſtrial Meridian anſwered to an *Amplitude* of one degree, at *Torneâ*, to produce the ſame difference of Meridional Altitude, an equal diſtance of 57000 Toiſes muſt be gone over in the Meridian.

IF

IF, on the contrary, the Surface of the Earth was a perfect Plane, how far ſoever one travelled Northward, the Meridional Altitudes of the Stars would ſuffer no change.

IF therefore the Surface of the Earth has, in different Climates, different degrees of Curvature; that is, if it approaches more or leſs to a perfect Plane, the Portions of the Terreſtrial Meridian, that, in different Climates, anſwer to the ſame Amplitude, muſt be of different Lengths. If the Earth is flatted towards the Poles, a Degree of the Terreſtrial Meridian will be longer towards the Poles than towards the Equator. And by the compariſon of diſtant Portions of the Terreſtrial Meridian that anſwer to a Degree, the Figure of the Earth may be determined.

HENCE it is clear, that to find the Length of a degree of the Terreſtrial Meridian, a certain Diſtance muſt be actually meaſured upon it, and the different Altitudes of the ſame Star muſt be taken at the two Extremities of that Diſtance, in order to compare the Length of the Arc with its Amplitude.

OUR firſt Work then was to meaſure ſome conſiderable Diſtance in the Meridian; and for that purpoſe to form a Series of Triangles connected with a Baſe, whoſe Length we could take by an actual Survey.

WE had all along flattered ourſelves that we might perform our Operations upon the Coaſts of the Gulph of *Bothnia*. The convenience of tranſporting ourſelves and our Inſtruments to the different Stations, by Sea, with the many advantageous Points of View which the Iſlands, as they are marked in all the Charts, ſeemed to promiſe us, had turned our Thoughts altogether upon theſe Coaſts and Iſlands. But when we had gone with great impatience to view them, all our labour ſerved only to convince us, that our firſt Deſign was impracticable. Theſe Iſlands, which line the Coaſts of the Gulph, and the Coaſts themſelves, which we had fancied to be ſo many Promontories, that might furniſh us with diſtant Points of View from one to another, lay all of them ſo low upon the Surface of the Water, that at a ſmall diſtance, the Convexity of the Earth muſt ariſe between them and us. Near the Coaſt they

even

even covered one another from our ſight: Nor did they advance far enough into the Sea to afford us the Direction we wanted. So that after ſeveral ſmall Voyages in purſuance of our firſt Deſign of making uſe of theſe Iſlands, we were at laſt obliged to give it up.

I had ſet out from *Stockholm* to *Torneå* in a Coach, with the reſt of the Company: but about the middle of this long Journey, having accidentally fallen in with the Veſſel that carried our Inſtruments and Servants, I had gone on board and was got to *Torneå*, ſome days before my Companions. At my landing, I had found the Governour of the Province juſt ſetting out to viſit North *Lapland*, which was of his Department; and had ſeized the occaſion of his Company, to get ſome notion of the Country till my Friends ſhould come up. I had advanced 15 Leagues to the North, paſſed the Night of the Solſtice upon *Avaſaxa*, one of the higheſt Mountains in the Country, and had got back to *Torneå* by the time my Companions arrived. In this Excurſion, which took up three Days, I had obſerved that the River of *Torneå*, as far as I had traced it, followed

pretty nearly the Direction of the Meridian, and that there were high Mountains on every ſide that might furniſh very diſtant Points of View.

HENCE we took the hint of performing our Operations upon the tops of theſe Mountains, to the Northward of *Torneå*; but the thing appeared next to impoſſible.

IN the Deſarts of a Country ſcarcely habitable, in that immenſe Foreſt which extends from *Torneå* to *Cape Nord*, we muſt go through Operations that are not eaſy even where no Convenience is wanting. To penetrate into theſe Deſarts, there were but two ways, both of which we muſt prove; one, the ſailing upon a River full of Cataracts; the other, croſſing thick Woods and deep Marſhes on foot. And if we ſhould be able to make our way into the Country, after the moſt painful Marches, we muſt have to clamber up ſteep Rocks, and clear the tops of Mountains of the Wood that intercepted our Sight. We muſt in theſe Deſarts put up with the moſt wretched Diet, expoſed to the Flies, which in this Seaſon are ſo inſufferable as to drive the *Laplanders*

and

and their Rain-Deer from their Habitations to ſeek ſhelter on the Coaſts of the Ocean. In fine, we muſt undertake this Work without knowing, or being able to inform our ſelves, whether it was at all practicable; whether the want of one Mountain might not, after all our Toils, abſolutely interrupt the Series of our Triangles; or whether it would be poſſible to find upon the River, a *Baſe* with which they could be connected. If none of theſe Obſtacles proved inſurmountable, ſtill there remained the Labour of building *Obſervatories* upon the moſt Northerly of the Mountains, the carrying thither as numerous a Collection of Inſtruments as is perhaps to be ſeen in *Europe*, and there making the niceſt Obſervations of Aſtronomy.

THESE were Obſtacles ſufficient to alarm us; yet on the other hand our Views were too charming to be parted with. Beſides the Pleaſure of conquering ſo many Difficulties, we ſhould have ſurveyed a Portion of the Earth, the remoteſt that is perhaps within the reach of Mortals; the Degree of the Meridian that cuts the *Polar Circle*, and lies partly within the *frozen Zone*.

Then,

Then, as we had deſpaired of making any uſe of the Iſlands in the Gulph, this was really the only Reſſource that remained. For to go down again to the more Southerly Provinces of *Sweden*, was a Thought we could not bear.

July, 1736. WE ſet out then from *Torneå* on *Friday* the 6th of *July*, with a Company of *Finland* Soldiers, and a good number of Boats laden with Inſtruments, and ſuch Proviſions as were thought moſt neceſſary.

WE began our Journey by ſailing up the great River, that riſing in the inmoſt Parts of *Lapland*, purſues its courſe till it falls into the Gulph of *Bothnia*, having firſt divided itſelf into two Branches that form the Iſle of *Swentzar*, where is built a Town of the ſame Name in the Latitude of 65°. 51′. From this day forward, our only Habitation was the Deſarts, and the Summits of thoſe Mountains which we were to connect by our Triangles.

AFTER a Voyage of twelve hours, we landed about Nine in the Evening at *Korpikyla*, a Hamlet by the River-ſide, inhabited by

by *Finlanders.* And having travelled acroſs the Foreſt on foot for ſome time, we arrived at the Bottom of a ſteep Mountain called *Niwa*, whoſe Summit, a bare Rock, we choſe for our firſt Station. Upon the River we had been tormented by great Flies with green Heads, that fetch blood whereever they fix. But on the top of *Niwa* we had to deal with ſeveral other kinds ſtill more intolerable. By good luck we found two *Lapland* Girls tending a ſmall Herd of Rain-Deer, but almoſt quite hid in the Smoke of a great Fire they had kindled: And upon enquiry being told it was in this manner they defended themſelves from the Flies, we immediately had recourſe to the ſame Method. *July.*

THE 8th of *July*, at One in the Morning, Mr. *Camus* and I left our Company upon *Niwa*, to go and reconnoitre the Mountains to the Northward. We travelled up the River, to a high Mountain called *Avaſaxa*, where having cleared its top of the Trees, we order'd a *Signal* to be built. Our Signals were hollow Cones, compoſed of a great many large Trees ſtript of the Bark. By this means they were white enough to be

July. be visible at the distance of 10 or 12 Leagues. And we had taken the precaution to cut Marks upon the Rocks, and drive Stakes into the Ground, covering them with large Stones, that, in case of any Accident, we could easily recover the Centre of our Cone. In short, our Signals were as convenient for Observation, and as solid as most Edifices in the Country.

AS soon as this was finished, we came down from *Avasaxa*, and embarking on the little River of *Tengliö*, which falls into the great River at the foot of this Mountain, we directed our Course upwards to a place the nearest we could find to a Mountain that seemed to suit our purpose. And from thence a March of three Hours over a Morass, brought us to the foot of *Horrilakero*. Though extremely fatigued, we got to the top of it, and passed the Night in cutting down the Wood that covered it. Most part of this Mountain is a reddish Stone, interspersed with a sort of white Crystal, of an oblong Form, and laid parallel-wise. Here the Flies, more merciless than those of *Niwa*, were not to be driven off by Smoke. We were obliged, notwithstanding the excessive Heats,

Heats, to wrap our Heads in our *Lappmudes*, (a ſort of Gown made of Rain-Deer Skins) and to cover us over with Branches of Firr, and even whole Trees; which rather ſtifled us, than defended us from theſe troubleſome Animals. *July.*

HAVING cut down all the Wood on the top of *Horrilakero*, and built a Signal, we returned by the ſame road, to find our Boats that we had drawn up upon the Bank, the People of this Country being but ill provided of Cordage to ſecure them in the ordinary way. 'Tis indeed no hard matter to drag along, or even carry the Veſſels that are uſed in the Rivers of *Lapland*. A few thin Firr-boards compoſe the whole Veſſel, ſo extremely light and flexible, that the continual beating, with all the force of the Stream, againſt the Stones which theſe Rivers are full of, does it no manner of harm. 'Tis terrible to thoſe that are not accuſtomed to it, and aſtoniſhing even to thoſe that are, to ſee one of theſe weak Machines drive down a Cataract, in a Torrent of Foam and Stones, ſometimes raiſed aloft in the Air, and next moment loſt in the Deep. A bold *Finlander* ſteers it with a long Oar, while

July. while his two Companions row hard to ſave it from the purſuing Wave that threatens every moment to overwhelm it. Then may you ſee the whole Keel by turns raiſed above Water, and leaning only with its one Extremity on the top of a yielding Billow. As theſe *Finlanders* have ſo much Courage and Addreſs in paſſing the Cataracts, their Art and Care in the management of their Boats upon other Occaſions is no leſs remarkable. A Tree, Branches and all, ſerves them ordinarily for both Sail and Maſt.

WE embarked again on the *Tengliö*, which brought us down into the River of *Torneå* on our return to *Korpikyla*. Four Leagues from *Avaſaxa* we left our Boats, and after an hour's march over the Foreſt, gained the foot of *Cuitaperi*, a ſteep Mountain, its Summit a Rock covered with Moſs, and affording an extenſive Proſpect all round; which, to the South, takes in the Gulph of *Bothnia:* Here we erected a Signal, whence we could diſcover *Horrilakero*, *Avaſaxa*, *Torneå*, *Niwa* and *Kakama*; and then continued our Courſe down the River. Between *Cuitaperi* and *Korpikyla* we found ſome frightful Cataracts,

racts, where the *Finlanders* always ſet their Paſſengers aſhore. But our exceſſive fatigue had made it more ſupportable to riſque paſſing them in the Boat, than to walk but an hundred Yards. At laſt, on the Evening of the 11th, we joined our Friends whom we had left on the top of *Niwa*: They had deſcryed our Signals, but, by reaſon of the continual Fogs, had not been able to make any Obſervations. *July.*

WHETHER it is the Sun's long Stay above the Horizon, that raiſes more Vapour than the Night can condenſe, I ſhall not determine. This is certain, that, during the two Months we paſt on theſe Mountains, the Sky was never clear till a northerly Wind roſe to carry off the Fogs. This diſpoſition of the Air detained us ſometimes 8 or 10 Days upon one Mountain, waiting for a favourable Moment, when we might have a diſtinct View of the Objects we wanted to obſerve. Next Day after our return to *Niwa* we took ſome Angles, and the Day following, by the favour of a cold north Wind, we were able to finiſh our Obſervations.

THE

July. THE 14th we left *Niwa*, and while Meſſ^rs *Camus*, *le Monnier* and *Celſius*, went to *Kakama*, Meſſ^rs *Clairaut*, *Outhier* and myſelf, took the Road of *Cuitaperi*, whence the Abbé *Outhier* went the 16th to plant a Signal at *Pullingi*. The 18th we made our Obſervations, which, notwithſtanding ſome Interruption from the Thunder and Rain, were compleated that ſame Evening. The 20th we ſet out all together, and by Midnight arrived at *Avaſaxa*.

THIS Mountain is ſituated on the bank of the River 15 Leagues from *Torneå*. Its Aſcent is difficult, lying through a Wood that reaches half way up, is then interrupted by a heap of ſteep ſlippery Rocks, and afterwards continued to the very top of the Mountain, at leaſt before we cut down ſo much of it as was neceſſary to open our Proſpect. The north-eaſt ſide is a moſt frightful rocky Precipice, where the Falcons build their Neſts. At the foot of it runs the *Tengliö*, encircling *Avaſaxa* before it falls into the River of *Torneå*. From its Summit the Proſpect is the moſt beautiful that can be imagined; to the South quite un-

unbounded, and diſcovering the courſe of the River to a vaſt extent. Towards the Eaſt one can trace the *Tengliö* in its paſſage through ſeveral Lakes. And on the North, at a diſtance of 12 or 15 Leagues, the View is terminated by a prodigious Number of Hills, heaped one upon another, as we uſe to repreſent the *Chaos*, and amongſt which it might not be eaſy, after one had got thither, to diſtinguiſh the one he had pitch'd upon at *Avaſaxa*. *July.*

WE ſpent 10 Days upon this Mountain, during which, Curioſity procured us frequent Viſits from the Inhabitants. They brought us Fiſh and Sheep, and ſuch bad Fruits as their Woods produce.

BETWEEN this Mountain and *Cuitaveri*, the River is exceeding broad, forming a ſort of Lake; which, beſides its extent, was very conveniently ſituated for our *Baſe*. Meſſ^rs^ *Clairaut* and *Camus* undertook to determine its direction, and ſtayed for that purpoſe at *Öfwer-Torneå*, after we had finiſhed our Obſervations at *Avaſaxa*: While I, with Meſſ^rs^ *le Monnier*, *Outhier* and *Celſius*, ſhould go up to *Pullingi*. The day

July. we left *Avaſaxa* we croſſed the *Polar Circle*; and on the Morrow, the 31ſt of *July*, by Three in the Morning arrived at *Turtula*, a ſort of Hamlet where they were cutting their little crop of Barley and Hay. After having travelled ſome time in the Wood, we embarked on a Lake which brought us to the foot of *Pullingi*.

THIS is the higheſt of all our Mountains, and of an exceeding difficult Acceſs; as well on account of its Steepneſs, as the depth of the Moſs wherein we had to fix our Steps: We reached the top however at ſix in the Morning. Our Stay here from the 31ſt of *July* to the 6th of *Auguſt* was no leſs diſagreeable than the Aſcent had been painful. We had to fell a whole Wood of the largeſt Trees. And the Flies attacked us with ſuch Fury, that our Soldiers of the Regiment of *Weſtro-Bothnia*, a Body diſtinguiſhed even in *Sweden*, where there are ſo many brave Troops; theſe Men, hardened with the greateſt Fatigues, were obliged to wrap up their Faces, or cover them with Tarr. Theſe Inſects poiſoned our Victuals too; no ſooner was a Diſh ſerved, but it was quite covered over with them, while another

another ſwarm, with all the rapaciouſneſs of Birds of prey, was fluttering round to carry off ſome pieces of a Sheep that was a dreſſing for us. *July.*

THE Morrow after our arrival at *Pullingi*, the Abbé *Outhier* went with an Officer of the Regiment of *Weſtro-Bothnia*, to whoſe good Offices we are very much indebted, to build a Signal towards *Pello*; and the 4th we diſcovered another which the ſame Gentleman had erected upon *Niemi*. Having taken the Angles between theſe *Signals*, we left *Pullingi* the 6th of *Auguſt* to go to *Pello*, where, after having forced our way up four Cataracts, we arrived the ſame day. *Auguſt.*

PELLO is a Village inhabited by a few *Finlanders:* In its Neighbourhood is *Kittis*, where was one of our Signals; the loweſt of all our Mountains. As we were going up we diſcovered a copious Spring of pure Water, that iſſues from a fine gravel, and reſiſts the keeneſt Froſt. For when we returned to *Pello* about the end of Winter, while the Sea at the bottom of the Gulph, and all the Rivers were frozen as hard

Auguſt. as Marble, we found this Spring running as in Summer. We had the good fortune to make our Obſervations ſoon after our arrival, ſo that we were obliged to ſtay at *Kittis* but till next day. We ſet out from thence at three o' clock in the Afternoon, and came the ſame Evening to *Turtula.*

FOR a Month paſt we had been Inhabitants of the Deſarts, or rather of the Mountains tops; the Earth or Rocks, ſpread with the Skin of a Rain-Deer, had been our Beds, and our Food chiefly Fiſhes that the *Finlanders* brought us, or which ourſelves had catch'd, with ſome ſort of Berries or wild Fruits that grew in the Woods. This way of living did by no means agree with Mr. *le Monnier.* His Health had been ſenſibly upon the Decline, eſpecially from the hardſhips we had ſuffered upon *Pullingi*, and being now quite gone, I was obliged to leave him at *Turtula* to go down the River, and try to recover it at the Curate of *Öfwer-Torneå*'s Houſe, which was the beſt, and almoſt the only place of Shelter in the Country.

I left *Turtula* at the ſame time in company with Meſſ^rs *Outhier* and *Celſius*, to go

go acroſs the Foreſt and find out the Signal which the Officer had erected at *Niemi*. *Auguſt.* And a frightful Journey it was. We ſet out from *Turtula* on foot till we got to a Brook, where we embarked on three little Boats. But they paſſed with ſuch difficulty between the Stones, that we had to go out of them at every turn, and leap from one Rock to another. The Brook brought us to a Lake ſo full of little yellowiſh Grains, of the bigneſs of Millet, that the whole Water was diſcoloured with them. I took them to be the *Chryſalis* of ſome Inſect, and was tempted to fancy that this Inſect muſt be ſome kind of thoſe Flies that ſo tormented us; for I could think of no other Species of Animals whoſe Numbers correſponded to the quantity of Grains that covered this large Body of Water. From the Extremity of this Lake we had to walk to another of very clear Water. Here we found a Boat, and putting our Quadrant on board, reſolved to follow it along the ſide of the Lake on foot. But the Wood was ſo thick, that we were forced to cut our way through it, and were entangled at every ſtep by the depth of the Moſs and the fallen Firr-trees that lay acroſs our Road. In all theſe Woods

Auguſt. there are almoſt as many fallen Trees as ſtanding. The Soil, after it has reared them to a certain height, can no longer furniſh the proper Nouriſhment, nor is it deep enough to allow them to take firm root. The leaſt blaſt of Wind overſets them, and in all theſe Woods one ſees nothing but Firrs and Birches rooted out in this manner. The wood of the latter, Time reduces to Duſt without at all affecting the bark; and one is ſurprized to find pretty large Trees that crumble upon the ſlighteſt touch. This has probably given the hint of the uſe the *Swedes* make of it, to cover their Houſes; and indeed there could be nothing imagined fitter for the purpoſe. In ſome Provinces they cover the Bark with Earth, which forms upon the Roof a ſort of Garden, ſuch as are to be ſeen upon the Houſes of *Upſal.* In *Weſtro-Bothnia*, the Bark is bound with Firr-Poles, fixt a-top, and hanging down on either ſide of the Roof. Our Woods then had rather the Aſpect of the Ruins of Woods whoſe Trees have moſt of them periſhed: And it was thro' one of theſe, one of the moſt horrid of them too, that we muſt paſs, with the twelve Soldiers that carried our Baggage. Having at length reach'd a third

Lake

Lake very large, and the fineſt Water that can be imagined, we put our Inſtruments and Baggage on board two Boats we found there, and waited their return upon the Coaſt. The high Winds, and bad Condition of theſe Boats rendred their Paſſage tedious. Yet they came back at laſt, and ferry'd us over to the foot of *Niemi* by Three o' Clock in the Afternoon. *Auguſt.*

THE beautiful Lakes that ſurround this Mountain, and the many difficulties we had to overcome in getting thither, gave it the Air of an enchanted Iſland in a Romance. And indeed any where but in *Lapland* it would be a moſt delightful place. On one hand you ſee a grove of Trees riſe from a Plain, ſmooth and level as the Walks of a Garden, and at ſuch eaſy diſtances as neither to embarraſs the Walks, nor the Proſpect of the Lake that waſhes the foot of the Mountain. On the other you have Appartments of different Sizes, that ſeem artificially cut in the Rock, and to want only a Roof to compleat them. And the Rocks themſelves ſo perpendicular, ſo high and ſo ſmooth that you would take them for the Walls of an unfiniſhed Palace rather than for the work

Auguſt. of Nature. From this height we had Occaſion ſeveral times to ſee theſe Vapours riſe from the Lake, which the People of the Country call *Haltios*, and which they deem to be the guardian Spirits of the Mountains. We had been frighted with Stories of Bears that haunted this place, but ſaw none. It ſeemed rather a place of reſort for *Fairies* and *Genii* than for Bears.

THE Day after our Arrival, the Fog hindered our Obſervations. The 10th we ſuffered ſome Interruption from the Thunder and Rain, but the Day following we had them compleated, left *Niemi*, repaſſed our three Lakes, and were got back to *Turtula* by Nine in the Evening. We parted from *Turtula* on the 12th, and at three in the Afternoon joined our Friends at the Curate's of *Öfwer-Torneå*, where leaving Mr. *le Monnier* and the Abbé *Outhier*, I ſet out the 13th with Meſſ^rs *Clairaut*, *Camus* and *Celſius* for *Horrilakero*. We entred the *Tengliö* with four Boats. Its Cataracts are troubleſome, rather for the little Water there is, and the great number of Stones, than for the rapidity of its Stream. As we ſailed along I was ſurprized to ſee, upon the banks

of

of this River, Roſes of as lively a red as any that are in our Gardens. About Nine at Night we reached *Horrilakero*, but our Obſervations were not finiſhed before the 17th. The 18th we returned to *Öfwer-Torneå*, where our whole Company was now aſſembled. *Auguſt.*

THE moſt convenient place for our *Baſe* had been already pitched upon. Meſſ^rs^ *Clairaut* and *Camus*, after having carefully viewed the banks of the River, had determined its Direction, and fixed its Length by Signals raiſed at either Extremity.

HAVING gone up to *Avaſaxa* in the Evening to take the Angles which muſt connect this *Baſe* with our *Triangles*, we ſaw *Horrilakero* all in flames. It is an Accident not uncommon in theſe Woods, where there is no living in the Summer time without Smoke, and where the Moſs and Firrs are ſo combuſtible, that a Fire once kindled will ſpread over ſome thouſands of Acres. Theſe Fires, or their Smoke, have ſometimes retarded our Obſervations as much as the thickneſs of the Air. As this burning of *Horrilakero* had been no doubt occaſioned by our not taking ſufficient care

to

Auguſt. to extinguiſh our Fires, we diſpatched 30 Men to cut off its Communication with the neighbouring Woods. But on the 21ſt, after we had finiſhed our Obſervations at *Avaſaxa*, *Horrilakero* was ſtill burning; we ſaw it involved in a Cloud of Smoke, and the Fire that had made its way downwards was ravaging all the Foreſt below.

SOME of the People that were ſent to *Horrilakero* having reported that our Signal was damaged by the Fire, we ſent to repair it; and by the precautions above-mentioned its Centre was not hard to find.

THE 22d we went to *Poiky-Torneå* upon the banks of the River, where the Signal at the North end of the *Baſe* ſtood, to take the Angles that muſt connect it with the tops of the Mountains. And next Day we ſet out for *Niemiſby*, where the South Signal had been erected, in order to make the like Obſervations. We lay this Night in a pleaſant Meadow; whence Mr. *Camus* parted next Morning for *Pello*, to prepare ſome Hutts where we might lodge, and to order an Obſervatory to be built on *Kittis*, where we were to make our Aſtro-

nomical Obſervations for determining the *Amplitude* of our Arc. *Auguſt.*

AFTER having made our Obſervation at the South end of the *Baſe*, we went up in the Evening to *Cuitaperi*, where our laſt Obſervation for connecting the Baſe with the Triangles was finiſhed the 26th.

HAVING lately received the News of our *Sector* we expected from *England* being arrived at *Torneå*, we made all haſte to return thither, to prepare this Inſtrument, and the others we were to carry to the Obſervatory at *Kittis*; becauſe as the Severity of the Winter was more to be apprehended upon *Kittis* than at *Torneå*, we reſolved to begin our Obſervations for the Amplitude of the Arc, at this end of our Meridian, before the extreme Colds ſhould come on. While every thing was getting ready for the Voyage of *Pello*, we went up to the Spire of a Church ſituated in the Iſle of *Swentzar* (which muſt not be confounded with the Church of the *Finlanders*, in the Iſle of *Biörcköhn*, to the ſouthward of *Swentzar*) and having taken the Angles which this Spire made with our Mountains, we ſailed from *Torneå* the 3d

of

Septem. of *September*, with fifteen Boats, the greateſt Fleet that had ever been ſeen upon the River; and lay that Night at *Kuckula*.

NEXT Day we arrived at *Korpikyla*; and while the reſt of the Company continued their rout to *Pello*, I ſet out on foot for *Kakama* with Meſſ^rs^ *Celſius* and *Outhier*, where we arrived at 9 o'clock at Night in the midſt of a heavy Rain.

THE top of *Kakama* is all of a white Stone diſpoſed in thin Plates, and ſeparated by vertical Planes that cut the Meridian at right Angles; theſe Stones had ſo collected the Rain that had been falling of a long time, that, except the very points of the Rocks, there was not the leaſt Spot that was not full of Water; and beſides, it continued to rain upon us all Night long. It was not poſſible for us to finiſh our Obſervations before the 6th; which coſt us a ſecond Night's lodging upon this Mountain, as wet and cold as the former.

WE left our Station of *Kakama* without regret. And the continual Rains with the encumbered Paſſage we had to make, through

through the Wood, having obliged us to exert our utmoſt diligence, a five hours march brought us back to *Korpikyla*, where we reſted that night, and ſetting out next morning, reached *Pello* on the 9th of *September*, where our whole Company was now once more united. *Septem.*

OUR ſeveral Courſes, in the 63 days we had paſt in theſe Deſarts had furniſhed us as compleat a Set of Triangles as we could have wiſhed for; and an Undertaking begun in ſome ſort at random, without knowing if it was at all practicable, had turned out ſo much better than Expectation, that it looked as if the placing of theſe Mountains had been at our own diſpoſal. The Mountains, with the Church of *Torneå* formed a Figure encloſed on every ſide, within which lay *Horrilakero* as a ſort of Centre, where the ſeveral Triangles that conſtituted it, met. The Figure it ſelf was an oblong Heptagon, placed in the direction of the Meridian, and happened, from a Property of Polygons, to be capable of a Verification that is ſingular in this ſort of Operations. The Sum of the Angles of a Heptagon upon a Plane is 900 Degrees; and as ours was upon a convex Surface, the Sum of its Angles muſt neceſſarily be ſome-

Septem. what greater: accordingly after having observed 16 Angles, we found it to amount to 900°. 1′. 37″. Near the middle of the *Heptagon* lay our *Baſe*, the longeſt that was ever uſed, and in the planeſt Surface, ſeeing it was upon the Ice of the River we were to meaſure it. The length of our Baſe warranted the Preciſion of our Meaſures of the Heptagon; and its Situation in the midſt of ſo ſmall a number of Triangles ſecured us againſt any Error of conſequence.

BESIDES, the Arc of the Meridian we were to meaſure was of a juſt length to give our Operations the greateſt degree of Certainty. If there is this advantage in making uſe of large Arcs, that the Errors one may commit in determining the *Amplitudes* are the ſame, whether the Arc is great or ſmall, and that a ſmall Arc will be more affected by the ſame Error than a great one: on the other hand, the Errors in the Trigonometrical Concluſions will be ſo much the more conſiderable as the Length meaſured is greater, and as the number of Triangles increaſes. If their number is very great, and if there is no Opportunity of correcting the Work, by the help of different Baſes, theſe laſt Errors may multiply each other into a Sum that

ſhall

ſhall more than ballance the advantage ari- *Septem.*
ſing from the largeneſs of the Arc. I had, before I left *Paris*, read a *Memoire* upon this Subject to the *Academy*, wherein I determine the length of the Arc that gives the greateſt degree of Certainty. Its quantity depends upon a Compariſon of the Exactneſs with which the Horizontal Angles can be taken, with that with which the diſtance of a Star from the *Zenith* can be obſerved. And if my Reaſonings in that Paper are applied to our Operation, it will appear that an Arc either much longer or much ſhorter would not ſo well have ſerved our purpoſe.

IN taking the Angles between our Signals, we made uſe of a *Quadrant* of two foot *Radius*, with a *Micrometer* fitted to it, which being verified a great many times round the *Horizon*, always gave the Sum of the Angles very nearly equal to 360°. We took care to place its Centre in the Centre of our Signals. Each made his Obſervation, and wrote it down apart: and then we took the *Mean* of all theſe Obſervations, which indeed differed very little from one another.

UPON every Mountain we had taken care to mark the Elevation or Depreſſion of the

Septem. the adjoining Signals ; and upon these Observations is founded the Reduction of the Angles of our Figure to the Plane of the *Horizon.*

OUR Success in this first part of our Work, where we might have met with Difficulties that it was impossible for us to get over, gave us fresh Courage for that which remained, where Labour only and Industry were required.

IN a Series of Triangles, joined to each other by Sides that are common, and whose Angles are known ; if a Side of any one of these Triangles is given, it is easy to find all the rest. We could not then fail to know exactly the distance between the Spire of the Church of *Torneå*, which terminated our Heptagon on the South, to its North Extremity at the Signal of *Kittis*, once we had measured the length of our Base.

THIS Operation might well be put off till Winter ; when we should have all the Leisure and all the Ice we could desire. So we turned our Thoughts to the other Branch of

of our Work, the Determination of the Arc of the Meridian that lies between *Torneå* and *Kittis*. I have already explained wherein this Determination conſiſted. We had to obſerve by how much the ſame fixt Star, as it paſſes the Meridian, appears higher or lower at *Torneå* than at *Kittis*. Or in other words, by how much this Star, as it paſſes the Meridian, is nearer or farther from the Zenith of the one than of the other of theſe two Places. The difference between theſe two Heights, or theſe two Diſtances from the *Zeniths*, is the *Amplitude* of the Arc of the Meridian between *Kittis* and *Torneå*. The Operation is ſimple; it is not even neceſſary to know the abſolute diſtances of the Star from the Zenith of each Place, it is ſufficient if we have their Difference. Yet, with all its Simplicity, it requires the moſt ſcrupulous Exactneſs and Caution. For this purpoſe we had procured a Sector of about 9 foot Radius, like that which Mr. *Bradley* uſes, and with which he made his curious Diſcovery of the *Aberration* of the fixt Stars. It was made at *London* under the Direction of that ingenious Artiſt Mr. *Graham*, a Fellow of the *Royal Society*, who had exerted himſelf to give it all the Advantages and all *Septem.*

Septem. the Perfection that could be wiſhed for. He had even taken the trouble to divide its Limb with his own hands.

IT were endleſs to give a particular deſcription of every thing that is remarkable in this Inſtrument. The main Part is very ſimple; but its Size, the great number of Pieces there are for rendering it manageable, the Weight of a large Pyramid twelve foot high, that ſupports it; all this together made it no eaſy matter to raiſe it to the top of a Mountain of *Lapland*.

WE had built two Obſervatories upon *Kittis*; in the one was a Quadrant of two foot Radius, a Clock of Mr. *Graham*'s, and an Inſtrument which we owed to the ſame Gentleman, conſiſting of a Teleſcope perpendicular to, and moveable about an horizontal Axis. This we placed preciſely at the Center of the Signal that made the angular Point of our laſt Triangle. Its Uſe was to determine the direction of our Triangles with reſpect to the Meridian. The other Obſervatory, which was much larger, was built ſo near the firſt, that the Voice of him that counted the Pendulum's Vibrations could

could be diſtinctly heard from the one to the other. The Sector almoſt took up the whole Room. What difficulty we had in carrying up ſo many Inſtruments to the top of the Mountain, I ſhall not mention; it is ſufficient that we carried them up. The Sector's Limb we placed exactly in the Plane of a Meridian Line which we had traced; and verified its Situation by the time of the Paſſage of a Star, ſeveral Altitudes of which we had taken. In ſhort, every thing was in readineſs for beginning our Obſervations, by the 30th of *September*; and the day following we made ſeveral upon the Star ♪ of the *Dragon*, all agreeing to within leſs than 3 Seconds. *Septem.*

IN the mean time, other neceſſary Obſervations were not neglected; we regulated our Clock every day by correſpondent Altitudes of the Sun; and obſerved with the above mentioned Inſtrument, the Paſſage of the Sun in the Meridian, and the Hour when he paſt the Verticals of *Niemi* and *Pullingi*. By this means we determined the Poſition of our Heptagon, with regard to the Meridian: and taking the *Mean* of eight ſuch Obſervations, none of which differed from another by a full Minute, we found the

Septem. Angle which a Line joining the Signals of *Kittis* and *Pullingi* makes with the Meridian of *Kittis* to be 28°. 51′. 52″.

ALL theſe Obſervations were performed very ſucceſsfully: but the Rains and Fogs had ſo retarded them, that we were like to fall into a Seaſon of the Year that muſt cut off our Return to *Torneå*. Yet it was there we had to make the like Obſervations of the ſame Star: And this we wiſhed to have done as ſoon as poſſible, leſt the Motion of the Star ſhould, in a longer interval of Time, produce ſome Error, in caſe it had any Motion to us unknown.

IT is evident that this whole Operation depending upon the difference of the Meridian-Altitudes of the ſame Star ſeen from *Kittis* and from *Torneå*; this Star muſt, during the time of the Obſervations, either keep fixt to the ſame Point of the Heavens, or at leaſt, if it does not, the Laws of its Motion muſt be known, that the difference of Altitude ariſing from its proper Motion may not be confounded with that which proceeds from the Curvature of the Arc of the Terreſtrial Meridian.

Septem.

ASTRONOMERS have, many ages ſince, obſerved a Motion of the fix'd Stars round the Poles of the *Ecliptic*, producing the *Preceſſion* of the *Equinoxes*, and a Change of *Declination* in the Stars. This can be eaſily taken into the account in the preſent Caſe.

BUT the Stars have another Change of *Declination*, which, however lately taken notice of, we may depend upon as ſurely as on that other. For though Mr. *Bradley* is the original Diſcoverer of this Variation, yet his Accuracy, and the Inſtrument he uſes, render his Obſervations equivalent to thoſe of many Ages. He has found, that in obſerving any Star for a whole Year together, it is ſeen to deſcribe in the Heavens a ſmall *Ellipſis*, whoſe great Axis is about 40″. This *Aberration* of the fixt Stars ſeemed at firſt ſubject to ſo great Varieties, that it was not till after a long Courſe of Obſervation that Mr. *Bradley* diſcovered the Theory upon which this Motion, or rather this Appearance depends. And if no leſs than the Accuracy of that Gentleman could have diſcovered this *Phenomenon*, no leſs than his Penetration

Septem. could have assigned its Cause. I shall not undertake to explain his System, which may be seen to much better purpose in *Phil. Trans.* N°. 406. I shall only add, that this change of Place in the fixt Stars seen from the Earth, proceeds from two Motions combined, that of the Rays of Light that come from the Star, and that of the Earth in its Orbit. If the Earth were fix'd, in order to look at a Star through a Telescope, the Telescope must have a certain Inclination, that a Ray of Light from the Star passing along its Axis, may reach the Eye. But if the Earth, carrying the Telescope along with it, moves with a Velocity that has any sensible Proportion to the Velocity of Light, its Inclination must now be altered, else a Ray of Light coming along its Axis cannot enter the Eye: and the different Positions of the Telescope will depend on the several Directions in which the Earth moves at different times of the Year. A Calculation founded upon these *Data*, the Velocity (and Direction) of the Earth in its Orbit, and the Velocity of the Rays of Light, which is known from other Experiments, will produce a difference of *Declination* of the fixt Stars, agreeing with Mr. *Bradley*'s Observations; and thus

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by increasing or diminishing the Star's Decli- *Septem.*
nation, by the Angles that result from this Calculation, we may consider it as having remained absolutely fixt during the Interval of our Observations.

ALTHOUGH the annual Motion of the fixt Stars agrees perfectly with this Theory, yet Mr. *Bradley* has discovered that they have still another Motion, incomparably slower than these two mentioned, and which is not sensible but at the end of several Years. In the most scrupulous Strictness, this too should be taken into the account. But our Observations lay all within so narrow a compass of time, that its effect must have been quite insensible, or at least smaller than we could hope to measure with our Instruments. I did indeed consult Mr. *Bradley*, to learn if he had any late Observations of the two Stars we made use of to determine the Amplitude of our Arc. Although he had not observed them, because they are too far from his *Zenith* for his Instrument to take them in, yet he was pleased to send me his last Discoveries upon the *Aberration*, and this new-discovered Motion of the fixt Stars: and the Correction or Equation he sent me

Septem. for our *Amplitude*, in which he has had regard to the *Preceſſion* of the *Equinoxes*, the *Aberration*, and this *new Motion*, differs not ſenſibly from that which we made for the *Preceſſion* and *Aberration* only; as will appear from the detail of our Operations.

THOUGH then we may with ſufficient certainty depend upon the Correction for the *Aberration*; yet for the ſake of ſuch as may ſcruple to admit Mr. *Bradley*'s Theory, or may ſuſpect ſome other undiſcovered Motion in the fixt Stars, we wiſh'd that this Correction might be very ſmall; and, for this purpoſe, that the interval between our Obſervations, at *Kittis* and at *Torneå*, might be the ſhorteſt poſſible.

WE had had ſome Ice ever ſince the 19th of *September*, and Snow on the 21ſt. Some part of the River was already froze; and this firſt imperfect Ice might render it impaſſable either to Boats or Sledges for a great while.

BY ſtaying any longer at *Pello* we run a riſque of not being able to return to *Torneå*, till the time between our Obſervations ſhould be

be longer than we wiſhed. We might likewiſe loſe ſight of our Star, by the too near approach of the Sun in his annual Courſe; in which caſe we muſt have return'd to *Kittis*, in the midſt of Winter to make new Obſervations upon another Star: And to paſs the Winter Nights in making Obſervations upon the top of a Mountain, was a thing not to be attempted. *Octob.*

IF we ſet out preſently, we were in danger of being ſtopt by the Ice with all our Inſtruments, we knew not where, nor for how long time. Thus too our Obſervations upon *Kittis* might be rendered of no uſe; a Loſs which it muſt have been very difficult to retrieve in this Country, where all Summer long we could not pretend to obſerve any Star within the reach of our Inſtrument, on account of their ſmallneſs, and their being hid by continual Day-light: And where the Severity of the Winter rendered Obſervations upon *Kittis* impracticable.

HAVING carefully weighed all the difficulties on either ſide, we reſolved to venture on the Journey. Meſſ^rs^ *Camus* and *Celſius*

Octob. *Celsius* set out with the Sector the 23d. Messrs *Clairaut* and *le Monnier* followed next Day. And the Abbé *Outhier* and I on the 26th. And by a singular good Fortune landed safe at *Torneå* on the 28th of *October*; the People of the Country assuring us they had scarce ever known the River navigable at that time of the Year.

OUR Observatory at *Torneå* being already prepared for receiving the Sector, we fixed it in the Plane of the Meridian. The first of *November* it began to freeze harder, and on the morrow the River was quite shut up. The Ice, which thawed no more, was presently covered over with Snow. And this vast body of Water, but a few days before full of Swans and other Water-Fowls, was now one immense Plain of Ice and Snow.

Novem. ON the 1st of *November* we began to observe the same Star we had observed at *Kittis*; and with the same precautions and success, the greatest differences of our Observations amounting but to one Second. In all which Observations, a faint Day-light had served to illuminate the Threads of the Micro-

Micrometer. And taking the Mean of all our Obſervations, the Parts of the *Micrometer* being reduced to Seconds, and due regard had to the Change of Declination cauſed by the Preceſſion of the Equinoxes and other Motions of the Star, our *Amplitude* came out to be $57'.27''$. *Novem.*

OUR Work was now in a manner compleated. It was really determined whether the Earth was *flat* or *prominent* towards the Poles, without our knowing, however, on which ſide of the Queſtion the Determination fell, becauſe we had not yet meaſured our *Baſe*. This was an Operation in itſelf quite ſimple and eaſy, being no more than ſurveying the diſtance between the two Signals we had erected laſt Summer; but then this Survey was to be made upon the Ice of a River in *Lapland*, in a Country where the Cold was growing every day more inſupportable; and the diſtance itſelf more than three Leagues.

WE were adviſed to put off this Survey till the Spring; becauſe the Days ſhould then be longer, and beſides, the firſt meltings of the Snow, which are immediately *Decem.*

Decem. froze again, would turn its Surface into a Cruſt ſtrong enough to bear us; whereas, in the heart of Winter the Snows are commonly in the form of a ſmall dry Duſt, four or five foot deep, which it is impoſſible to paſs over. But the Apprehenſions of being ſurprized by a Thaw, however ill founded they may appear in the midſt of a Froſt that was growing keener every day, overballanced all other Conſiderations. What if we ſhould come too late, ſaid we, in the Month of *May*, and thus be entirely diſappointed in our Deſign.

IN the mean time, as we did not know whether the Snow upon the River might not be already too deep, Meſſ^rs. *Clairaut*, *Outhier* and *Celſius*, went on the 10th of *December* to view it. They found its depth conſiderable, yet not ſuch as to make us deſpair of meaſuring our Line; ſo we went all together to *Öfwer-Torneå*.

Mr. *Camus*, aſſiſted by the Abbé *Outhier*, employed the 19th and 20th in adjuſting eight Rods, each 30 foot long, by means of an Iron Toiſe we had brought from *France*, which during this Operation we kept in

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a place where Mr. *de Reaumur*'s Thermometer ſtood at 15 Degrees below 0, and that of Mr. *Prins* at 62; the Degree of Heat at *Paris* in *April* and *May*. Our Rods once adjuſted, were in no danger of ſuffering any Alteration in their length from the Cold. For we had found that Heat and Cold are far from producing any ſuch Extenſion and Contraction in Firr as they are known to do in Iron. All the Experiments we made produced differences in the length almoſt imperceptible. From ſome of them I was even inclined to think, that Wood is by the Cold rather lengthned than contracted; whether it is that a little Sap remaining in thoſe pieces of Wood we made trial with, might poſſibly freeze and ſwell as liquids do when they are expoſed to the Cold, and thus communicate ſomewhat of their Extenſion to the Wood. Mr. *Camus*'s care in adjuſting theſe Rods had been ſuch, that notwithſtanding their great length, when we applied their Extremities between two pieces of Iron, the thickneſs of a leaf of the fineſt Paper more or leſs, would allow them to paſs very freely or not at all. *Decem.*

ON

Decem. ON *Friday* the 21ſt of *December*, the Day of the Winter Solſtice, and a pretty remarkable one for ſuch an Enterprize, we began the meaſure of our *Baſe* towards *Avaſaxa*, where it lay. In this Seaſon the Sun but juſt ſhowed himſelf above the Horizon towards Noon. But the long Twilights, the whiteneſs of the Snow, and the Meteors that are continually blazing in this Sky, furniſhed us light enough to work four or five hours every day. At 11 in the Forenoon we left the *Curate*'s Houſe, where we had taken up our Quarters till this Work ſhould be finiſhed, and went upon the River to begin our Survey; attended by ſo many Sledges, and ſo great an Equipage, that the *Laplanders*, drawn by the novelty of the Sight, came down from the neighbouring Mountains. We parted ourſelves into two Bands, each of which carried four of the Rods juſt now mentioned. I ſhall ſay nothing of the Fatigues and Dangers of this Operation. Judge what it muſt be to walk in Snow two foot deep, with heavy Poles in our hands, which we muſt be continually laying upon the Snow and lifting again: In a Cold ſo extreme, that whenever we

we would taſte a little Brandy, the only thing that could be kept liquid, our Tongues and Lips froze to the Cup, and came away bloody: In a Cold that congealed the Fingers of ſome of us, and threatned us with yet more diſmal Accidents. While the Extremities of our Bodies were thus freezing, the reſt, through exceſſive Toil, was bath'd in Sweat. Brandy did not quench our thirſt; we muſt have recourſe to deep Wells dug thro' the Ice, which were ſhut almoſt as ſoon as opened, and from which the Water could ſcarce be conveyed unfrozen to our Lips; and muſt thus run the hazard of the dangerous contraſt which iced Water might produce in our heated Bodies. *Decem.*

OUR Work however advanced apace, ſix days labour had brought it to within about 500 Toiſes, where we had not been able to plant our Stakes ſoon enough. So we intermitted our meaſuring on the 27th, which Meſſ^rs^ *Clairaut*, *Camus* and *le Monnier* were to employ in planting theſe Stakes, while the Abbé *Outhier* and I went out upon an extraordinary enough Adventute.

LAST

Decem. LAST Summer we had omitted an Obſervation of very ſmall moment, and which might have been overlooked in a Country where the making Obſervations was leſs troubleſome than here. We had forgot to take the height of an Object that we made uſe of in meaſuring, from the Top of *Avaſaxa*, the Angle between *Cuitaperi* and *Horrilakero*. And to meaſure this height, I undertook to go with a Quadrant to the top of the Mountain; ſo ſcrupulouſly careful were we that nothing ſhould be wanting to the perfection of our Work. Imagine a very high Mountain, full of Rocks, that lie hid in a prodigious quantity of Snow, as well as their Cavities, wherein you may ſink thro' a Cruſt of Snow as into an Abyſs, and the Undertaking will appear ſcarce poſſible. Yet there are two ways of performing it. One is by walking, or rather ſliding along, upon two ſtrait Boards eight foot in length, which the *Finlanders* and *Laplanders* uſe to keep them from ſinking into the Snow. But this way of walking requires long practice. The other is by truſting yourſelf to a *Rain-Deer*, who is uſed to perform ſuch Journeys.

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THE Machine which these Animals draw is a sort of Boat scarce large enough to hold the half of one's Body. As this travelling in the Snow is a kind of Navigation, that the Vessel may suffer the less resistance in its Course, it has a sharp Head and a narrow Keel, like an ordinary Boat; and on this Keel it tumbles so from side to side, that if one takes not good care to ballance himself, it will be in danger of over-setting every moment. It is fixt by a thong to the Collar of the Rain-Deer, who, as soon as he finds himself on a firm beaten Road, runs with incredible Fury. If you would stop him, it avails little to pull a sort of Rein which is tied to his Horns. Wild and unmanageable, it will only make him change his Track, or perhaps turn upon you, and revenge himself by kicking. If this happens to a *Laplander*, he turns the Boat over him, and uses it as a Buckler against the Attacks of the Rain-Deer. But as we were Strangers to this Adresse, we might have been killed before we could put ourselves in such a posture of Defence. Our only Defence was a little Stick each of us had got in his hand, by way of Rudder *Decem.*

Decem. to ſteer our Courſe, and keep clear of the Trunks of Trees. In this manner was I to climb *Avaſaxa*, accompanied by the Abbé *Outhier*, two Men and a Woman of the Country, and Mr. *Brunnius* their Curate.

THE firſt part of our Journey was done in a moment; our flight over the plain beaten Road from the Curate's Houſe to the foot of the Mountain can be compared only to that of Birds. And tho' the Mountain, where there was no track, very much abated the ſpeed of our Rain-deer, they got at length to the top of it; where we immediately made the Obſervation for which we came. In the mean time our Rain-deer had dug deep holes in the Snow, where they browzed the Moſs that covers the Rocks. And the *Laplanders* had lighted a great Fire, at which we preſently joined them to warm ourſelves. The Cold was ſo exceeding great, that the Heat of this Fire could reach but to a very ſmall diſtance. As the Snow juſt by it melted, it was immediately froze again, forming a hearth of Ice all round.

IF our Journey up hill had been painful, our Concern now was leſt our return

ſhould

ſhould be too rapid. We had to come down a ſteep, in Conveyances, which, though partly ſunk in the Snow, ſlid on notwithſtanding, drawn by Animals whoſe Fury in the Plain we had already try'd, and who, though ſinking in the Snow to their Bellies, would endeavour to free themſelves by the Swiftneſs of their flight. We very ſoon found ourſelves at the bottom of the Hill; a moment after, all this great River was croſſed, and we back at the Curate's Houſe. *Decem.*

NEXT day we finiſhed our Survey; and had now no reaſon to regret the Toils we had gone thro', when we ſaw what ſurprizing exactneſs the meaſuring upon a Surface of Ice had given us. The difference between the Meaſures of our two Companies was but four Inches upon a diſtance of 7406 Toiſes 5 feet. An exactneſs not to be expected, and almoſt incredible. We look upon it as an effect of Chance, and that there muſt have been greater differences, but which in the courſe of our Work had compenſated each other; for this ſmall difference of four Inches roſe all in our laſt day's meaſuring. Each of our Bands had meaſured every day the ſame number of

Decem. Toiſes; and the difference every day was but one Inch which the one or the other had gained. This coincidence, which was owing partly to the Ice, and partly to our own Accuracy, ſhewed at the ſame time the perfect equality of our *Rods*; for the ſmalleſt difference in their lengths, muſt, in ſo great a diſtance, have been multiplied to a conſiderable Sum.

WE already knew the *Amplitude* of our Arc; and our Figure, every other way determined, wanted only to be applied to its *Scale*, that is, to the length of our Baſe. This we were now Maſters of; and immediately found that the length of the Arc of the Meridian intercepted between the two Parallels that paſs through the Obſervatories of *Torneå* and *Kittis* is 55023 ½ Toiſes. That the *Amplitude* of this Arc being 57′. 27″. the Degree of the Meridian at the Polar Circle is greater by 1000 Toiſes than it ſhould be according to Mr. *Caſſini*, in his Treatiſe *On the Magnitude and Figure of the Earth.*

THIS Operation ended, we made haſte to get back to *Torneå*, to ſecure ourſelves

ſelves the beſt we could againſt the growing Severity of the Seaſon. *Decem.*

THE Town of *Torneå*, at our Arrival on the 30th of *December*, had really a moſt frightful Aſpect. Its little Houſes were buried to the tops in Snow, which, if there had been any day-light, muſt have effectually ſhut it out. But the Snows, continually falling, or ready to fall, for moſt part hid the Sun the few moments that he might have ſhowed himſelf at Mid-day. In the Month of *January* the Cold was increaſed to that extremity, that Mr. *Reaumur*'s Mercurial Thermometers, which at *Paris*, in the great Froſt of 1709, it was thought ſtrange to ſee fall to 14 Degrees below the freezing point, were now got down to 37. The Spirit of Wine in the others was frozen. If we opened the door of a warm room, the external Air inſtantly converted all the Vapour in it into Snow; whirling it round in white Vortexes. If we went abroad, we felt as if the Air were tearing our Breaſts in pieces. And the cracking of the Wood whereof the Houſes are built, as the violence of the Cold ſplit it, continually alarmed us with an approaching in-

Decem. creaſe of Cold. The Solitude of the Streets was no leſs than if the Inhabitants had been all dead: And in this Country you may often ſee People that have been maimed, and had an Arm or a Leg froze off. The Cold, which is always very great, increaſes ſometimes by ſuch violent and ſudden Fits, as are almoſt infallibly fatal to thoſe that happen to be expoſed to it. Sometimes there riſe ſudden Tempeſts of Snow, that are ſtill more dangerous. The Winds ſeem to blow from all Quarters at once, and drive about the Snow with ſuch Fury, that in a moment all the Roads are loſt. Unhappy he who is ſurprized by ſuch a Storm in the Fields. His Acquaintance with the Country, or the Marks he may have taken by the Trees, cannot avail him. He is blinded by the Snow, and loſt if he ſtirs but a ſtep.

IF the Earth in this Climate is thus horrible, the Heavens preſent to the Eye a moſt beautiful Proſpect. As ſoon as the Nights begin to be dark, Fires of a thouſand Colours and Figures light up the Sky, as if deſigned to compenſate, to a Country accuſtomed to ſuch length of day, the abſence of the Sun in this Seaſon. Theſe Fires have not here,

as

as in the more ſoutherly Climates, any con- *Decem.*
ſtant Situation. Though you may often ſee a luminous Arch fixed towards the North, they ſeem more frequently to poſſeſs the whole Extent of the Hemiſphere. Sometimes they begin in the form of a great Scarf of bright Light, with its Extremities upon the Horizon, which, with a Motion reſembling that of a Fiſhing-Net, glides ſwiftly up the Sky; preſerving in this Motion a direction nearly perpendicular to the Meridian. Moſt commonly, after theſe Preludes, all the Lights unite at the Zenith, and form the top of a ſort of Crown. Arcs like thoſe we ſee towards the North in *France*, are here frequently ſituated towards the South: And oftimes towards both North and South at once. Their Summits approach each other, while the diſtance of their Extremities widens towards the Horizon. I have ſeen ſome of the oppoſite Arcs whoſe Summits almoſt joined at the Zenith: And both the one and the other have frequently ſeveral concentric Arcs beyond it. Their tops are all placed in the Direction of the Meridian, though with a little Declination to the Weſt; which I did not find to be conſtant, and which ſometimes is inſenſible.

Jan^y. 1737. ſenſible. Some of theſe Arcs have their greateſt width at the Horizon; which contracting as they riſe, gives them the form of more than half a great Ellipſe. It were endleſs to mention all the different Figures theſe Meteors put on, and the different Motions wherewith they are agitated. Their Motion is moſt commonly like that of a pair of Colours waved in the Air, and the different Tints of their Light give them the appearance of ſo many vaſt Streamers of that ſort of Taffetas which we call *changeable*. Sometimes they line a part of the Sky with Scarlet. On the 18th of *December* I ſaw at *Ofwer-Torneå* a Phenomenon of this kind, which raiſed my Admiration, in the midſt of all the Wonders I was now every day accuſtomed to. There appeared to the South, a great ſpace of the Sky tinged with ſo lively a red, that the whole Conſtellation of *Orion* look'd as if it had been dipt in blood. This Light, which was fixt at firſt, ſoon moved, and changing into other colours, Violet and Blue, ſettled into a Dome, whoſe top ſtood a little to the South-weſt of the Zenith. The Moon ſhone bright, but did not in the leaſt efface it. In this Country, where there are Lights of ſo many

diffe-

different colours, I never saw but two that were red; and such are taken for Presages of some great Misfortune. After all, when People look at these Phenomena with an unphilosophic eye, it is not surprizing if they discover in them fiery Chariots, Armies engaged, and a thousand other Prodigies. *Jan^y.*

WE had shut our selves up at *Torneå* in a kind of inaction, till the Month of *March* that we could venture out upon new Discoveries.

IN the mean time, the great difference of our Arc, from what it must have come out upon Mr. *Cassini*'s Hypothesis, astonished us; and we resolved, however inconteſtable our Operations were, to submit the whole Process to a most rigorous Examination.

AS for our Triangles, their Angles had been observed so often, and by so great a number of Persons, that this part of our Work could fall under no manner of suspicion. It had even an advantage above any thing that has been done in this kind. It has commonly been thought sufficient to find two Angles of a Triangle by Observation, and the third by subtracting their Sum.

Jan^y. Sum from 180 Degrees. This Method would have been extremely convenient for us, and would have ſaved us many a diſagreeable hour upon the tops of theſe Mountains; yet we had willingly ſacrificed this Convenience to the pleaſure of knowing from actual Obſervation every Angle in our Figure.

BESIDES, tho' to determine the Diſtance between *Torneå* and *Kittis*, no more than 8 Triangles were abſolutely neceſſary, we had obſerved ſeveral ſupernumerary ones, and by this means our Heptagon furniſhed us Combinations or Series of Triangles without number.

THUS one part of our Work had been done, one may ſay, a great many times over; and there remained only to calculate and find what different Lengths might reſult from theſe different Series of Triangles. We had the patience to make trial with no leſs than 12 Series; and though ſeveral of our Angles were too ſmall to be admitted in ſuch Calculations, the higheſt difference in the diſtances of *Kittis* and *Torneå*, deduced from theſe Series, roſe but to 54 Toiſes. We pitched upon two, which we judged preferable

ferable to the others, and which gave a dif- *Jan.*
ference of $4\frac{1}{2}$ Toiſes. And the *Mean* of this we uſed to determine the Length of our Arc.

SUCH a perfect Agreement would have ſurprized us, if we had not remembred what pains and time had been beſtowed upon the taking of theſe Angles. Eight or nine Triangles had coſt us 63 days; and every Angle had been obſerved ſo often, and by ſo many different Perſons, that the *Mean* of them all could not but come very near the Truth.

THE ſmall number of our Triangles enabled us to make an odd enough Calculation, which gives the ſtrict limits of all the Errors that bad ſkill and bad luck put together can produce. We made a ſuppoſition, that in every Triangle we had committed an Error in two of the Angles of 20″ each, and in the third of 40″; and that all theſe Errors lay the ſame way, tending always to diminiſh our Arc. And having made a computation upon this ſtrange Suppoſition, we found that the Error could amount to but $54\frac{1}{4}$ Toiſes.

OUR

Jan^y.

OUR extreme Care in meaſuring the Baſe left no room to ſuſpect we had failed in this part. The agreement of ſo many ſkilful Perſons, who writ down, each ſeparately, the number of Rods, and the repeating of this Meaſure with a difference of no more than 4 Inches, were a more than ſufficient ſecurity.

WE turned therefore the reſt of our Scrutiny upon the *Amplitude* of the Arc. The ſmall difference there was amongſt our Obſervations, both at *Kittis* and at *Torneå*, left no doubt as to the manner of Obſerving.

AND conſidering the Solidity and Conſtruction of our Sector, with the Precautions we had taken in carrying it from Place to Place, there was no great ground to fear it had met with any accident to put it out of order.

ITS Limb, Teleſcope and Centre, make up but one Piece, and the Threads in the Focus of the Object-Glaſs, are two Silver Wires, fixed by Mr. *Graham* himſelf, ſo as they can ſuffer no change in their ſituation, and remain always

always in the ſame degree of Tenſion, whether it is hot or cold. Thus the only diſorder that could happen to this Inſtrument would be the bending of its Teleſcope. *Janv.*

BUT upon calculating the effects of any Alteration of this ſort, it will appear, that to occaſion an Error of one Second in the Amplitude of our Arc, there muſt be a bending ſo conſiderable as to be very eaſily perceived. Incloſed in a ſtrong Caſe it had been conveyed in a Boat from *Kittis* to *Torneå*, under the care of one of us, put on ſhore at the Cataracts, and carried by Men.

THE ſituation of the Star which we had obſerved, enſured us againſt what happens to the Teleſcopes of large Inſtruments, when they are directed to an Object at a conſiderable diſtance from the Zenith; their weight alone muſt bend them while they are in this inclined Poſition: and the method of obſerving with the two different Sides of the Inſtrument, tho' it may prevent ſome other Miſtakes, cannot correct this. For if in obſerving with the face of the Inſtrument towards the Eaſt, the Teleſcope has ſuffered any Inflexion, when you turn its face to the Weſt,

Jan^y. Weſt, it will ſuffer nearly the ſame Inflection the contrary way; ſo that the ſame Point may anſwer to the Zenith in either Obſervation, and yet the Star's diſtance from the Zenith not be juſtly meaſured. The diſtance of our Star from the Zenith of *Kittis* was but half a Degree, and conſequently our Teleſcope, in a ſituation ſo erect, could ſuffer no alteration.

THOUGH, on all theſe accounts, we had no reaſon to doubt of our Amplitude's being accurately meaſured; yet we would be aſſured by experience that it was ſo; and for this purpoſe employed a Method which was indeed the moſt troubleſome, but muſt be at the ſame time the moſt ſatisfactory, as it would at once diſcover to us the goodneſs of our Inſtrument, and how far we might depend upon the Accuracy of our Obſervations.

THIS Verification conſiſted in determining the ſame Amplitude by the means of another Star. We watched therefore an occaſion of making ſome Obſervations near one another, which is difficult in a Country where there are ſeldom three or four clear Nights together.

And on the 17th of *March* 1737, having be- *March.*
gun, at *Torneå*, in the ſame place as before, to obſerve α of the *Dragon*, and got three good Obſervations of this Star; we ſet out for *Kittis* to make the like Obſervations there. Our Sector was conveyed upon a Sledge that went very ſlowly upon the Snow; the ſoft-eſt Carriage that can be imagined. Our new Star was nearer ſtill to the Zenith than the former, being ſituated but a quarter of a Degree from the Zenith of *Torneå*.

WE could readily place our Inſtrument by means of the Meridian Line that had been drawn in our Obſervatory at *Kittis*; and the 4th of *April*, began our Obſervations of *April.* α; three of which compared with thoſe of *Torneå*, gave for the Amplitude $57'.\ 30''\frac{1}{2}$, which exceeds that found by the Star δ by $3'\frac{1}{2}$; allowance being made for the Aberration of Light: and if the Aberration is not taken into the account, the difference would not be $1''$.

A difference ſo very inconſiderable, that it might be owing to the Errors in obſerving, and which, as will appear from the Sequel, was ſtill leſs than it appeared, was a ſtrong Proof both

April. both of the goodneſs of the Inſtrument, and of the truth of our Obſervations.

TAKING now a *Mean*, between the Amplitude found by the Star ♌ and that found by α, the true Amplitude comes to be 57′. 28″$\frac{3}{4}$, which compared with the meaſured Length of 55023$\frac{1}{2}$ Toiſes, gives for the Degree that cuts the Polar Circle, 57437 Toiſes, exceeding that of Mr. *Picard* between *Paris* and *Amiens* by 377 Toiſes.

BUT it muſt be obſerved, that the *Aberration* of the fixt Stars was not known, nor could be taken into the account by Mr. *Picard*. If his *Amplitude* is corrected by *it*, and by the *Preceſſion* of the *Equinoxes* and *Refraction*, both which he had neglected, it will be 1°. 23′. 6″$\frac{1}{2}$, which compared with the diſtance meaſured 78850, gives to a Degree 56925, ſhort of ours by 512 Toiſes.

AND if the *Aberration* was ſet aſide, our Amplitude would be reduced to 57′. 25″, which compared with the Arc would give to the Degree 57497, exceeding 57060 Toiſes, which Mr. *Picard* had found in a Degree,

Degree, without reckoning the *Aberration April.* by 437.

LAST of all; with the Aberration, our Degree differs by 950 Toiſes from what it ſhould be by Mr. *Caſſini*'s Book; and ſetting aſide the Aberration, by 1000.

WHENCE it is evident, *That the Earth is conſiderably flatted towards the Poles.*

DURING our whole Stay in the *frigid Zone*, the Cold was ſo exceſſive, that the 7th of *April* at 5 in the Morning, the Thermometer was fallen to 20 Diviſions below the Point of Freezing, although every Afternoon it roſe two or three Diviſions above it: a difference of height not much leſs than that which the greateſt Heats and Colds that are felt at *Paris* uſually produce in the Thermometer. Here, in the ſpace of 12 hours, we had all the variety that is felt in the temperate Zones in a whole Year.

WE carried our Scrutiny even to the direction of the Heptagon, with reſpect to the Meridian. This Direction, as above mentioned, had been determined upon *Kittis* by

April. a great number of Obſervations of the Sun's Paſſage by the Verticals of *Niemi* and *Pullingi*, and it was not probable we had miſplaced our Figure, the Triangles that compoſed it being ſo few in number, and the Sum of its Angles coming ſo near to juſt 900 Degrees: yet we choſe to ſettle this Point once more, at *Torneå*.

WE took a different Method from that which we had uſed at *Kittis*. We meaſured the Angle between the Sun in the Horizon, and one of our Signals, marking the time of the Obſervation: and three ſuch Obſervations gave us, at a *mean*, the ſame Angle, within 34″, as we had found at *Kittis*.

HAVING thus gone over every part of our Work a ſecond time, it remained only to examine the original Conſtruction and Diviſion of our Sector. There was not the leaſt reaſon to ſuſpect it; but having ſome leiſure till the Seaſon for travelling ſhould come on, we would employ a part of it in this Examination. Our Method deſerves a particular Deſcription, being ſingular; and of uſe to ſhew what may be expected from

ſuch

such an Instrument, and how to discover any Alteration it may chance to receive. *May.*

THE 4th of *May*, we laid out (still upon the Ice of the River) a Radius of 380 Toises, 1 Foot, 3 Inches, 0 Line; having measured it twice without finding any difference. We planted two firm Posts with two *Marks* in a Line perpendicular to the Extremity of this Radius, and having measured the distance between the Centers of the two *Marks*, we found it to be 36 Toises, 3 F. 6 In. $6\frac{2}{3}$ Lin. This Line was our Tangent.

WE placed the Sector horizontally in a Room, upon two firm Supports that rested upon a Vault, so that its Center was precisely at the Extremity of our Radius of 380 Toises, 1 F. 3 Inches; and five of us having severally taken the Angle between the two Marks, the greatest difference amongst our Observations not amounting to full 2″, their *Mean* was 5°. 29′. 52″,7. Now Mr. *Graham* had signified to us that the Arch of $5\frac{1}{2}$ Degrees on the Limb of this Instrument was too short by $3''\frac{3}{4}$; subtracting these $3''\frac{3}{4}$ our Angle is 5°. 29′. 48″. 95. But the Angle,

May. by Calculation, is $5^{\circ}. 29'. 50''$, differing from that obſerved by no more than $1''\frac{1}{10}$.

IT may ſeem ſurprizing that a Sector which, in ſo temperate a Climate as that of *London*, was found to be of $5^{\circ}. 29'. 56''\frac{1}{4}$, and was divided in a Room probably not cold, ſhould at *Torneå* remain preciſely of the ſame length, at the making this trial, when its parts were no doubt contracted by the Cold. But the ſurprize will ceaſe, if it is remembered, that this Inſtrument is all of the ſame matter, and that conſequently all its parts muſt be contracted proportionally, its figure remaining ſimilar to what it was before, as we found it had done.

HAVING found the total Arc of the Sector ſo exquiſitely juſt, we would next ſee if the two Degrees of its Limb, which we had uſed, the one for ♌ and the other for ♎, were perfectly equal. Mr. *Camus*'s Adreſſe, to which we had been obliged upon ſo many other occaſions, helped us to make this Compariſon with all the accuracy imaginable. And taking the Mean of 5 ſeveral Obſervations made by different Perſons, the Degree we had made uſe of for ♌ came out greater by $1''$ than that which we had uſed for ♎.

WE

WE were surprized to see that this inequality of the two Degrees made the small difference between our two Amplitudes still less, reducing it from $3''\frac{1}{2}$ to $2''\frac{1}{2}$. And it will appear from the detail of our Operations, and from the Method we used to discover it, that this difference, small as it is, may be reckoned upon with great Certainty.

IN the same manner we verified not only the total Arc of the Sector, but different Arcs which we compared together. And this Verification from Arc to Arc, joined to that of the whole, satisfied us that we could neither have wished nor hoped for any thing more exquisite in its kind.

WE could not conceive any thing more that remained for us to do, with respect to the measure of a Degree of the Meridian. For I shall say nothing at present of our Experiments upon *Gravitation*; a Subject no less important than the other, and which we treated with equal care. Let it suffice to assure whoever has a mind to examine the Earth's Figure by the Weight of Bodies, after the Example of Sir *Isaac Newton*, Mr. *Huy-*

May. *gens*, and others (to whoſe Names may I be permitted to add my own) that they will find all the Experiments we made in the North to that purpoſe, as well as thoſe we are told Meſſ^rs *Godin*, *Bouger*, and *la Condamine* have made at the Equator, will concur in making the Earth flat towards the Poles.

MEAN time, the Sun was now come nearer, or rather no more quitted us. It was curious enough to ſee him enlighten for ſo long a time, a whole Horizon of Ice, and to ſee Summer in the Heavens, while Winter ſtill kept poſſeſſion of the Earth. We were now in the Morning of that long Day of ſeveral Months; yet the Sun, with all his aſſiduity, had wrought no change either upon the Ice or Snows.

THE 6th of *May* it began to rain, and ſome Water appeared on the Ice of the River. At Noon a little Snow melted; but in the Evening, Winter reſumed his Rights. At length, on the 10th of *May*, the Earth which had been ſo long hid, began to appear; ſome high Points that were expoſed to the Sun, ſhewed themſelves, as the tops of the

Mountains did after the Deluge, and all the Fowls of the Country returned. Towards the beginning of *June*, Winter yielded up both Earth and Sea. We bethought us forthwith of our Journey back to *Stockholm*; and set out the 9th of *June*, some of us by Land, and others by Sea. But the Sequel of our Adventures, and our Shipwreck in the Gulph of *Bothnia*, belong not to the present Subject. *June.*

OBSERVATIONS

Made at the Polar Circle.

BOOK I.

PART I.

Containing the Operations for measuring the Degree of the Meridian.

CHAP. I.

Observations for forming the Triangles, and determining their Position, with respect to the Meridian Line.

I.

The Angles Observed.

ALL these Angles were taken with a Quadrant of 2 foot Radius, arm'd with a Micrometer; which Instrument verified several times round the Horizon, gave always the Sum of the Angles very near equal to 360°.

THE

THE Decimals of Seconds are marked as they arose in the arithmetical Reduction of the parts of the Micrometer to Seconds; but we would not for that be thought to pretend to an imaginary Exactness.

FOLLOWS a Table of the Angles observed, with the Elevations of the Objects, where the Sign + or — marks their being *above* or *below* the Horizontal Line.

Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*
In the Spire of the Church of Torneå.		
CTK.. 24 23 0,2	24 22 58,8	*C*.....0 0 Fig. 1.
And by the Reduction on account of the Centre of the Instrument its being 5 foot distant from the Centre of the Spire in the Direction of *Cuitaperi*		
CTK.....	24 22 54,5	
KTn.. 19 38 20,9	19 38 20,1	*n*.. +3 0
And by Reduction for the place of the Centre of the Instrument.		
KTn.....	19 38 17,8	*K*.. +8 40
		The Horizon of the Sea —11 0

Angles

Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*

Upon *Niwa.*

Fig. 1.

TnK..	87 44 24,8	87 44 19,4	*T*... —17 40
HnK..	73 58 6,5	73 58 5,7	*K*... +16 50
AnK..	95 29 52,8	95 29 54,4	*A*... + 4 40
AnH=AnK—HnK		21 31 48,7	*H*... — 0 30
AnH=	21 32 16,9	21 32 16,3	
Whence *AnH* is		21 32 2,5	
CnH..	31 57 5,2	31 57 3,6	*C*... + 10 0

Upon *Kakama.*

TKn...	72 37 20,8	72 37 27,8	*n*..... —22 50
CKn...	45 50 46,2	45 50 44,2	*C*.... — 4 45
HKn..	89 36 0,4	89 36 2,4	*H*.... — 5 10
HKC=nKH—CKn		43 45 18,2	
HKC..	43 45 46,8	43 45 47,0	
HKC..	43 45 41,5	43 45 41,7	
Whence *HKC* is		43 45 35,6	
CKT=CKn+nKT		118 28 12,0	*T*.... —24 10
HKN..	9 41 48,1	9 41 47,7	*N*.... — 8 10

Upon *Cuitaperi.*

			K.... — 6 10
KCn...	28 14 56,9	28 14 54,7	*n*..... —19 0
TCK...	37 9 15,0	37 9 12,0	*T*.... —24 10
HCK	100 9 56,4	100 9 56,8	*H*... — 2 40
ACH..	30 56 54,4	30 56 53,4	*A*... + 5 0

Angles

Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*

Upon *Avasaxa.*

	° ′ ″	° ′ ″
HAP..	53 45 58,1	53 45 56,7
HAx...	24 19 34,8	24 19 35,0
xAn...	77 47 46,7	77 47 49,5
xAC...	88 2 11,0	88 2 13,6
HAn=HAx+xAn		102 7 24,5
HAC=CAx+xAH		112 21 48,6
CAn...	10 13 54,2	10 13 52,8

P....	+ 4 50
H....	— 8 0
x.....	—10 40
C....	—14 15
n.....	—20 20

Upon *Pullingi.*

APH..	31 19 53,7	31 19 55,5	*H*.... —22 0
QPN	87 52 9,7	87 52 24,3	*A*.... —18 10
NPH	37 21 58,9	37 22 2,1	*Q*.... —32 40
			N.... —26 50

Upon *Kittis.*

NQP..	40 14 57,3	40 14 52,7	*P*.... +22 30
			N... + 1 0

Upon *Niemi.*

PNQ	51 53 13,7	51 53 4,3	*P*.... +18 30
PNH	93 25 8,1	93 25 7,5	*Q*.... —14 0
HNK	27 11 55,3	27 11 53,3	*H*.... — 2 40
			K.... —14 0

Angles

Angles observed.	*Angles reduced to the Horizon.*	*Elevations.*

Upon *Horrilakero.*

	°	′	″	°	′	″		′	″
CHn...	19	38	21,8	19	38	21,0	*n*....	—18	15
CHA..	36	42	4,3	36	42	3,1	*A*...	0	0
AHP..	94	53	49,7	94	53	49,7	*P*...	+11	50
PHN	49	13	11,9	49	13	9,3	*N*...	— 5	0
KHn..	16	26	6,7	16	26	6,3	*K*...	—12	30
CHK..	36	4	54,1	36	4	54,7	*C*...	—10	40

Angles for connecting the Base Bb *with the Tops of* Avaſaxa *and* Cuitaperi.

Angles observed.				*Angles reduced to the ſame Plan.*	*Elevations of the Objects ſeen from the Point* B.			
	°	′	″			°	′	″
ABb....	9	21	58,0	Reducing *ABy*, *yBC*, and *ABz*, *zBC* to the ſame Plan *ABC*, and taking a *Mean* between the two Values of *ABC* thus found, we had	*A*..	+0	40	30
AbB..	77	31	48,1					
BAb..	93	6	7,2					
ABy..	61	30	5,4		*y*...	+1	23	30
yBC..	41	12	3,4		*C*..	+1	4	5
ABz..	46	7	57,5		*z*...	+1	11	0
zBC..	56	34	22,2					
ACB..	54	40	28,8	*ABC*.. 102 42 13,5				
BAC..	22	37	20,6					

The Letters *x*, *y*, *z*, mark the intermediate Objects that were uſed to take the Angle *ABC* at twice, being greater than 90°.

II.

Obſervations upon Kittis *for drawing the Meridian Line.*

THE Inſtrument with which theſe Obſervations were made conſiſted of a Teleſcope 15 Inches long, moveable round a horizontal Axis to which it was perpendicular. This Inſtrument was placed upon the Centre of the Signal of *Kittis*, where the height of the Pole is 66°. 48′. 20″. and whoſe Longitude Eaſt from *Paris* anſwers, we ſuppoſe in that Calculation, to 1ʰ. 23′.

THERE was in the ſame place a Clock which we regulated every day by correſpondent Altitudes of the Sun. And the Hour of the paſſage of the Sun's Centre, which we determined by the paſſages of his two Limbs, is in this Table given in *true time*.

Paſ-

Paſſages of the Sun's Centre by the Vertical of the Signal of Pullingi.

1736. Afternoon.	h	′	″		°	′	″
30 Septemb. at	1	49	49	☉'s Decl. . . .	3	0	40
1 October at	1	50	7¼	☉'s Decl. . . .	3	24	1
2 October at	1	50	26	☉'s Decl. . . .	3	47	19
7 October at	1	51	54¾	☉'s Decl. . . .	5	42	56
8 October at	1	52	14½	☉'s Decl. . . .	6	6	10

Paſſages of the Sun's Centre by the Vertical of the Signal of Niemi.

1736. Before noon.	h	′	″		°	′	″
4 October at	11	16	37	☉'s Decl. . . .	4	31	22
7 October at	11	16	15¾	☉'s Decl. . . .	5	40	26
8 October at	11	16	12	☉'s Decl. . . .	6	3	39

CHAP.

CHAP. II.

The Angles formed by the Meridian Line with the Lines drawn from Kittis *to* Pullingi, *and to* Niemi.

THE Method we uſed, to find from theſe Obſervations, the above-mentioned Angles, conſiſts in reſolving the two ſpherical Triangles PZS, PZs, where we have given; the Side $PZ = 23°.\ 11'.\ 40''.$ being the diſtance of the Zenith of *Kittis* from the Pole; PS or Ps, the Compliment of the Sun's Declination at the time of Obſervation; and the Angle ZPS or ZPs, which is known from the time of the Sun's paſſage by the Vertical Zp or ZN of *Pullingi* or *Niemi*: Whence are found the Angles HZp and HZN, or HQp and HQN, which Lines drawn from *Kittis* to *Pullingi* and *Niemi* make with the Meridian. Fig. 3.

THE

THE Angles deduced from the ſeveral Obſervations are as follows:

	The Decl. of *Pullingi*, Weſt.			Decl. of *Niemi*, Eaſt.		
	°	′	″	°	′	″
30 Sept.	28	51	54			
1 Octob.	28	51	56			
2 Octob.	28	52	5			
4 Octob.	. . . . .			11	23	30
7 Octob.	28	51	43	11	23	23
8 Octob.	28	52	6	11	22	31

Fig. 3. AND having already (*page* 107.) the Angle $NQP = 40°.\ 14'.\ 52'',7$, theſe Declinations of *Niemi* are changed by ſubtraction into the following of *Pullingi*.

°	′	″
28	51	23
28	51	30
28	52	22

AND all theſe Declinations give, at a Mean, the Declination of *Pullingi*, or the Fig. 2. Angle $PQM = 28°.\ 51'.\ 52''$.

CHAP.

CHAP. III.

The Length of the Base; and the Calculation of the Triangles of the two principal Series.

I.

The Length of the Base.

Bb is the Base. It was measured two several times by two different Companies, whereof each had four Perches of 30 foot in Length. Fig. 1.

	Toiſ.	*f.*	*inch.*
The firſt Menſuration gave	7406	5	0
The ſecond	7406	5	4
Between which the mean length is . .	7406	5	2

II.

Calculation of the two Triangles with which all the Series begin.

A B b.

	Angles observed.		*Angles corrected for Calculat.*
	° ′ ″		° ′ ″
Fig. 1. *A B b*...	9 21 58,0	. . . .	9 22 0
A b B...	77 31 48,1	. . . .	77 31 50
B A b...	93 6 7,2	. . . .	93 6 10
	179 59 53,3		180 0 0

A B C.

A B C...	102 42 13,5	. . . .	102 42 12
B A C...	22 37 20,6	. . . .	22 37 20
A C B...	54 40 28,8	. . . .	54 40 28
	180 0 2,9		180 0 0

BY resolving these two Triangles, the *Base B b* being 7406 Toises, 5 Foot, 2 Inches, the distance *A C*, between *Avasaxa* and *Cuitaperi* is found to be 8659,94 Toises.

AND these two Triangles having been very accurately determined, and their disposition advantageous for finding this distance, *A C* may be henceforth used as a Base.

III. *Cal-*

III.

Calculation of the Triangles of the first Series.

A C H.

Angles observed, reduced to the Horizon.				*Angles corrected for* Fig. 2. *Calculation.*			
	°	′	″		°	′	″
CAH...	112	21	32,9	. . . .	112	21	17
ACH...	30	56	53,4	. . . .	30	56	47
AHC...	36	42	3,1	. . . .	36	41	56
	180	0	29,4		180	0	0

C H K.

CHK...	36	4	54,7	. . . .	36	4	46
CKH...	43	45	35,6	. . . .	43	45	26
KCH...	100	9	56,8	. . . .	100	9	48
	180	0	27,1		180	0	0

C K T.

KCT...	37	9	12,0	. . . .	37	9	7
CKT...	118	28	12,0	. . . .	118	28	3
CTK...	24	22	54,3	. . . .	24	22	50
	180	0	18,3		180	0	0

A H P.

	°	′	″		°	′	″
AHP...	94	53	49,7	....	94	53	56
HAP...	53	45	56,7	....	53	46	3
APH...	31	19	55,5	....	31	20	1
	179	59	41,9		180	0	0

H N P.

	°	′	″		°	′	″
HNP...	93	25	7,5	....	93	25	1
NHP...	49	13	9,3	....	49	13	3
HPN...	37	22	2,1	....	37	21	56
	180	0	18,9		180	0	0

N P Q.

	°	′	″		°	′	″
NPQ...	87	52	24,3	....	87	52	17
NQP...	40	14	52,7	....	40	14	46
PNQ...	51	53	4,3	....	51	52	57
	180	0	21,3		180	0	0

TAKING $AC = 8659{,}94$ Toiſes, as found above (*page* 114.) by means of the two Triangles *ABb*, *ABC*; by reſolving the foregoing Triangles we find,

Toiſes.

$AP = 14277{,}43$
$PQ = 10676{,}9$
$CT = 24302{,}64$

THESE

THESE Lines form with the Meridian the following Angles,

	°	'	"
PQD =	61	8	8
APE =	84	33	54
ACF =	81	33	26
CTG =	69	49	8

AND the Resolution of the right-angled Triangles DQP, APE, ACF, CTG, gives for the parts of the Meridian Line,

	Toises.
PD =	9350,45
AE =	14213,24
AF =	8566,08
CG =	22810,62
QM =	54940,39

for the Arc of the Meridian which passes thro' *Kittis*, and which is terminated by the Perpendicular drawn from *Torneå*.

IV.

Calculation of the Triangles of the second Series.

A C H.

	Angles observed, reduced to the Horizon.				*Angles corrected for Calculation.*			
		°	′	″		°	′	″
Fig. 2.	*ACH*...	30	56	53,4	. . . .	30	56	47
	CAH...	112	21	32,9	. . . .	112	21	17
	AHC...	36	42	3,1	. . . .	36	41	56
		180	0	29,4		180	0	0

C H K.

	CHK...	36	4	54,7	. . . .	36	4	46
	CKH...	43	45	35,6	. . . .	43	45	26
	KCH...	100	9	56,8	. . . .	100	9	48
		180	0	27,1		180	0	0

C K T.

	CKT...	118	28	12,0	. . . .	118	28	3
	CTK...	24	22	54,3	. . . .	24	22	50
	KCT..	37	9	12,0	. . . .	37	9	7
		180	0	18,3		180	0	0

H K N.

H K N.

HKN...	9	41	47,7	....	9	41 50
HNK...	27	11	53,3	....	27	11 56
KHN...	143	6	3,2	....	143	6 14
	179	59	44,2		180	0 0

H N P.

HNP...	93	25	7,5	....	93	25 1
HPN...	37	22	2,1	....	37	21 56
NHP...	49	13	9,3	....	49	13 3
	180	0	18,9		180	0 0

N P Q.

NPQ...	87	52	24,3	....	87	52 17
NQP...	40	14	52,7	....	40	14 46
PNQ...	51	53	4,3	....	51	52 57
	180	0	21,3		180	0 0

STILL making uſe of

Toiſes.

$AC = 8659{,}94$

we have by the Reſolution of theſe laſt Triangles,

Toiſes.

$QN = 13564{,}64$

$NK = 25053{,}25$

$KT = 16695{,}84$

WHICH Lines make with the Meridian Line,

	°	′	″
$N\mathfrak{Q}d$ =	78	37	6
KNL =	86	7	12
KTg =	85	48	7

THE Reſolution of the Triangles $\mathfrak{Q}Nd$, KNL, KTg, gives for the parts of the Meridian Line,

	Toiſes.
Nd =	13297,88
KL =	24995,83
Kg =	16651,05
$\mathfrak{Q}M$ =	54944,76
The other Series gave . . $\mathfrak{Q}M$ =	54940,39
Whence at a Mean . . $\mathfrak{Q}M$ =	54942,57

CHAP.

CHAP. IV.

To determine the true Length of an Arc of the Meridian, its Amplitude being known.

I.

THE Places of our Obſervatories anſwering to the Centre of the Sector, when we made our Obſervations upon the fixt Stars, were that of *Torneå* more Southerly by 73 Toiſes, 4 foot, $5\frac{1}{2}$ inches, than the point *T*, (the Spire of the Church, and Vertex of our firſt Triangle); this diſtance was meaſured upon the Ice of the River by letting fall Perpendiculars: And that of *Kittis* more to the North than the Centre of our Signal *Q*, by 3 Toiſes, 4 foot, 8 inches. Fig. 2.

ADDING then to *QM*, theſe two diſtances, we have $q\,m = 55020{,}09$ Toiſes.

II. THIS

II.

THIS Line $q\,m$ is not precisely the Arc of the Meridian answering to the difference of Latitude.

FOR the perpendicular $t\,m$ is not the Arc of the Parallel that passes through t: Supposing the Arc $t\,\mu$ to be this Parallel, to find the point μ, draw the Tangent $t\,\nu$, and divide the distance $m\,\nu$ equally.

TO find the Value of $m\,\nu$, first compute the length of $m\,t$, in the present case nearly equal to $M\,T$, which, by the Resolution of the foregoing Triangles, will be found to be 3149,5 Toises: From this Line found, and the Latitude of *Torneå* given, supposing likewise (which can here occasion no sensible Error) that the Earth is spherical, and that a Degree contains 57000 Toises; the Angle made by the Tangents of the two Meridians that pass through Q and T, that is the Angle $m\,t\,\nu$, will easily be found to be $7'.24''$. Whence $m\,\nu$ is 6,76 Toises, and its half 3,38 Toises $= m\,\mu$, added to the distance $q\,m$, gives for the Arc

of

of the Meridian, whose Amplitude was observed, $q\mu = 55023{,}47$ Toises.

CHAP. V.

Observations to determine the Amplitude of the Arc of the Meridian, terminated by the Parallels that pass through Kittis *and* Torneå.

I SHALL not at present give a compleat Description of the Instrument we made use of; that would carry me too far, and is reserved for another Work. I shall endeavour only to explain what is peculiar to this Instrument, and give my Readers such a Notion of it as may enable them to understand the tryals we made of its goodness as well as the Observations themselves.

A Brass Telescope, of a considerable thickness, and about nine foot long, forms the Radius of a Limb of $5^{\circ}\frac{1}{2}$. This Limb has upon it two Divisions, both of them from $7'\frac{1}{2}$ to $7'\frac{1}{2}$; the one to a shorter Radius, marked

marked with greater points; the other to a longer Radius marked with ſmaller. At the Focus of the Teleſcope two Silver Wires croſs each other; Mr. *Graham* himſelf had fixt them in the firmeſt manner; and contrived, by means of two Springs, to keep them always in the ſame degree of tenſion, that they may not be ſubject to the leaſt Alteration. This Teleſcope, the Centre to which the Plumb-line is hung, and the Limb, are all one piece, and properly make up the whole Inſtrument; which will not therefore be ſo readily put out of order as one whoſe Centre can be taken off. It is ſuſpended by by two cylindric Pins, that reſting upon two Braſs Supports, allow it to ſwing freely like a Pendulum. One of the Pins ends in a very ſmall Cylinder; which is ſtill more diminiſhed where it meets the plane of the Limb, whoſe Centre it is. At this point of the Axis of the Pin is ſuſpended the Plummet. And round the ſame Axis the Teleſcope moves; while its Limb, by the means of two Wheels, ſlides along another immoveable Limb, which is fixt to a large Beam that paſſes through the middle of a great wooden Pyramid that ſupports the Inſtrument. To the immoveable Limb is

fixt

fixt the Micrometer, at the place moſt convenient for the Obſervation that is to be made. The uſe of the Micrometer is as follows:

THE immoveable Limb, and that of the Sector being placed in the Plane of the Meridian, the Teleſcope, as it hangs upon its Pins, would reſt in a vertical Situation. But a ſmall weight hung upon a Thread that paſſes over a Pulley, draws it Southward: While the Micrometer puſhes it the contrary way, by means of a point of Steel that reſts againſt a piece of hard poliſht Steel, fixt upon the Teleſcope. The motion of this Point towards the Mirror or from it, is regulated by a very fine Screw; making the Teleſcope deſcribe ſmall Arcs; while two Indexes mark the number of Revolutions, with the parts of a Revolution, by which the Point has advanc'd or retir'd. Theſe Revolutions meaſure then the Amplitude of the Arc obſerved, provided it is known how many Minutes and Seconds anſwer to one Revolution, by which the Point of the Micrometer goes backward or forward.

THE

THE proportion of the Number of Revolutions to the Arcs muſt vary as the place where the Point reſts upon the Speculum is higher or lower; and therefore on a Plate of Braſs that covers the Speculum when it is not made uſe of, there is drawn a Line marking where the Point of the Micrometer ought to reſt, ſo as to make the Revolutions of a determinate proportion to the Arcs. You may place the Point higher and lower till you get it exactly upon the Line: And then you have the ſituation of the Micrometer, upon which the Proportion is regulated.

IN obſerving, the firſt thing we did was to place exactly under the Thread of the Plummet that point of the Limb which was neareſt to where we knew the Plummet muſt cut in the time of Obſervation, the Ball of the Plummet being in the mean time immerſed in a Veſſel fill'd with Brandy. And this can be done to ſuch an Accuracy, by the help of the Micrometer and a Microſcope, on whoſe Focus the Light ſtrikes perpendicularly to the Limb, that placing and diſplacing the Thread ſeveral times,

times, you will rarely find one Diviſion of the Micrometer, that is to ſay, one Second of Difference. When the Thread, inſtead of hanging freely, reſted upon Pegs, as in the tryals we made for verifying the Inſtrument, we ſeldom had more than $\frac{1}{4}$ of a Second's Difference between one placing and another. An Accuracy which may ſeem incredible to ſuch as have never ſeen an Inſtrument like ours; but they will be better able to judge of it when they have conſidered the Obſervations made with it by ſo many different Perſons.

BEFORE the Star was to paſs the Meridian, we wrote down the Diviſion which was marked by the Micrometer, when the Thread exactly cut the Point upon the Limb. And juſt as the Star paſt the Meridian, the Obſerver, without being able to ſee the Micrometer, turned the Skrew, till he ſaw the Star biſſected in the Teleſcope, by the Thread that is perpendicular to the Limb. Then we reckoned how many Revolutions and Parts of a Revolution the Screw had made. And theſe added to the Arc terminated by the Point which the Plummet cut before the Obſervation, or

ſubtracted from it, gave the Point of the Limb where the Plummet muſt have cut when the Star paſſed the Meridian. And laſt of all, we verified the Obſervation by replacing the Point under the Thread, as it had been before the paſſage of the Star. If the Micrometer marked ſtill the ſame Revolution as it had marked before the Paſſage, or if the difference was but one or two Diviſions, then the Obſervation was held as good. And we took the Mean between the two Numbers of the Micrometer, before and after the Obſervation, for the true Number which it marked when the Point of the Limb was exactly under the Thread. But if the difference of theſe two Numbers was more than two Diviſions, we concluded that the Inſtrument muſt have been diſturbed ſome how, and that the Obſervation was not to be depended upon.

THE two Stars which we obſerved with this Inſtrument paſt the one within leſs than $\frac{1}{2}$ Degree from the Zenith of *Kittis*, and the other not $\frac{1}{4}^{\circ}$ from that of *Torneå*. A Situation which might render us very ſecure as to any Errors ariſing from a wrong poſition of the Sector; which in other caſes,

if great care is not taken, may be very conſiderable. We knew that the miſplacing it by ſeveral Minutes could have no ſenſible Effect upon our Obſervations; yet we placed it moſt exactly by a Meridian Line which we had drawn, and verified its poſition by the paſſage of ſome Stars whoſe heights we had taken.

II.

Obſervations of the Star ſ of the Dragon *made with the Sector upon* Kittis, *for determining the Amplitude of the Arc of the Meridian.*

The 4th of October, 1736.

BEFORE the Obſervation of the paſſage of the Star in the Meridian, the Thread of the Plummet having been placed upon the point of the Limb marked 2°. 37′. 30″. of the upper Diviſion, which we always made uſe of, the Micrometer marked . . . . . Revol. 24 10,7 parts, whereof 44 go to a Revol.

IN the time of Obſervation, that is, when the Star was paſſing the Meridian, the Micrometer marked . . 22 30,9

	Rev. part.
AFTER the Obſervation the ſame Point 2°. 37′. 30″. being replaced under the Thread, the Micrometer marked	24 12,5
THE Mean of what the Micrometer marked before and after the Paſſage is . .	24 11,6
AND ſubtracting	22 30,9
RESTS, in parts of the Micrometer, the Arc between the point 2°. 37′. 30″. and that where the Thread had cut when the Star was in the Meridian, *viz.*	1 24,7

5 Oct.	Before the Obſerv. . .	24 13,3
	In the time of Obſerv.	22 31,4
	After	24 15,3
		24 14,3
		22 31,4
	Difference	1 26,9

6 Oct.

		Revol.	part.
6 October	Before the Obſerv. . .	24	9,8
	In the time of Obſerv.	22	28,2
	After	24	9,8
		24	9,8
		22	28,2
	Difference	1	25,6
8 October	Before the Obſerv. .	18	1,0
	In the time of Obſerv.	16	16,7
	After	17	43,0
		18	0
		16	16,7
	Difference	1	27,3
10 Octob.	Before the Obſerv. .	17	33,0
	In the time of Obſerv.	16	8,3
	After	17	33,1
		17	33,0
		16	8,3
	Difference	1	24,7

THESE Obſervations were made by Day-light, without artificially illuminating the Focus of the Teleſcope.

III.

Observations of the same Star made at Torneå.

1736.

THE Thread of the Plummet cutting the Point of the Limb marked 1°. 37′. 30″. of the upper Division ;

The Micrometer marked,

		Rev.	parts.
1 Nov.	Before the Observ. . . .	17	39,5
	In the time of Observ. .	19	36,3
	After	17	40,5
		17	40,0
		19	36,3
	Difference	1	40,3
2 Nov.	Before the Observ. . . .	18	13,1
	In the time of Observ. .	20	8,8
	After	18	12,0
		18	12,5
		20	8,8
	Difference	1	40,3

3 Nov.

		Rev.	parts.
3 Nov.	Before the Obſerv. . . .	18	37,0
	In the time of Obſerv. .	20	33,3
	After	18	35,0
		18	36,0
		20	33,3
	Difference	1	41,3
4 Nov.	Before the Obſerv. . . .	18	32,2
	In the time of Obſerv. .	20	28,4
	After	18	31,0
		18	31,6
		20	28,4
	Difference	1	40,8
5 Nov.	Before the Obſerv. . . .	12	24,4
	In the time of Obſerv. .	14	20,5
	After	12	24,0
		12	24,2
		14	20,5
	Difference	1	40,3

THESE Obſervations were likewiſe made by Day-light.

CHAP. VI.

Calculation of the Arc of the Meridian which we had observed.

	Rev. parts.
The Obſervations upon *Kittis* give	1 24,7
	1 26,9
	1 25,6
	1 27,3
	1 24,7
Whoſe Mean is	1 25,8
The Obſervations at *Torneå* give	1 40,3
	1 40,3
	1 41,3
	1 40,8
	1 40,3
Whoſe Mean is	1 40,6

WE have then for the Arc of the Limb which the Thread cut as the Star paſſed the Merid. at *Kittis* $2^{\circ}\ 37'\ 30''$ — Rev. parts. 1 25,8

AND for the like Arc at *Torneå* . . . . $1\ 37\ 30$ + 1 40,6

WHOSE

WHOSE difference is that of the Star's diſtance from the Zeniths of *Kittis* and *Torneå*, viz.

°	′	″	Rev. parts.
1	0	0	—3 22,4

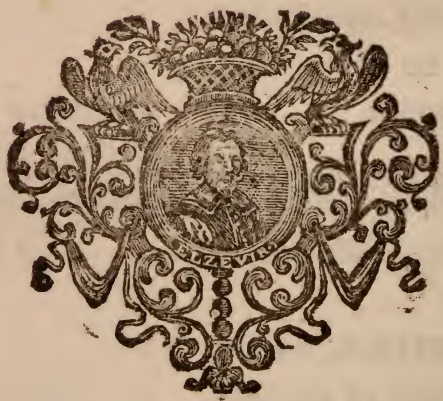
TO reduce the Revolutions and Parts of the Micrometer into Minutes and Seconds, it is to be noticed (vid. *infra*) that

	R. P.	′	″
15′ = 20 Rev. 23,5 Parts, whence . . .	3 22,4 =	2	33,8

	°	′	″
Which taken from . .	1	0	0
give the Arc obſerved .	0	57	26,2

FURTHER, by the Conſtruction of the Sector, the Chord of $5^{\circ}\frac{1}{4}$, which is 10,625 Inches *Engliſh*, is too little for the Radius, which is 110,75 by 0,002; that is, by $3''\frac{3}{4}$; which $3''\frac{3}{4}$ upon $5^{\circ}\frac{1}{2}$ give for $57'\frac{1}{2}$ the

proportional part to be subtracted, ...			0,65
leaving for the Arc observed, ...	57	25,55	



PART

PART II.

Containing Verifications of the whole Work.

CHAP. I.

Verification of the Horizontal Angles by their Sum round the Heptagon.

	°	′	″	
CTK	24	22	54,5	Fig. 1.
KCT	37	9	12,0	
KCH . . .	100	9	56,8	
HCA	30	56	53,4	
CAH	112	21	48,6	
HAP	53	45	56,7	
APH	31	19	55,5	
HPN	37	22	2,1	
NPQ	87	52	24,3	
PQN	40	14	52,7	
QNP	51	53	4,3	
PNH	93	25	7,5	
HNK	27	11	53,3	
NKH	9	41	47,7	
HKC	43	45	35,6	
CKT	118	28	12,0	

THEIR Sum 900 1 37, exceeds by 1′. 37″, what it ſhould be if the Figure lay

lay in a plane Surface, and if there was no Error in the Obſervations; it ought indeed to be a little more than 900, becauſe of the Earth's Convexity.

CHAP. II.

Verification of the Heptagon, made at Torneå.

Fig. 4. THE Centre of the Quadrant of two foot Radius being placed in the Line paſſing through the *Spire* of the Church and the Signal of *Niwa*, we took the Angle which the horizontal Sun made with the Signal of *Niwa*, marking the time by a Clock which we had carried to the higheſt place of the Iſle *Swentzar*, and whoſe Hour we compared ſeveral times, by means of Signals, to that of a well-adjuſted Pendulum in the Houſe where I lodged.

1737, *the* 24*th of* May *at Night.*

True Time.

h ′ ″ ° ′ ″
At 9 55 16...*nCS*...13 36 26 = THE Angle between the Signal of *Niwa* and the Centre of the Sun, concluded from the Paſſage of his two Limbs by the vertical Wire in the Teleſcope.

SUPPOSING the Sun's Declination to be 20°. 53′. 29″,7, and the Latitude of the place of Obſervation 65°. 51′. 0″. *RCS* is found = 28°. 55′. 48″, The Angle of the Vertical of the Sun with the Meridian Line for the moment of Obſervation; from which ſubtracting *nCS* already found (13° 36′ 26″), remains *RCn* or *RTn* = 15 19 22 for the Angle which the Meridian Line forms with a Line joining the Spire of *Torneå* and the Signal of *Niwa*.

1737, *the* 25*th of* May, *in the Morning.*

THE Centre of the Quadrant placed in the direction of *Kakama* and the Spire of *Torneå*.

True Time.

Fig. 5. At $2^h\ 3'\ 5''$ ....*nCS*.. $44^\circ\ 6'\ 34\frac{1}{2}''$ THE Angle between the Signal of *Niwa* and the Centre of the rising Sun.

nCK..19 52 34 THE Angle observed at the same place between the Signals of *Niwa* and *Kakama*.

KCS..24 14 $0\frac{1}{2}$ ANGLE between the Signal of *Kakama* and the Sun.

RCS..28 32 48 THE Angle of the Vertical of the Sun, with the Meridian calculated for the Moment of Observation, the Sun's Declination being 20°. 55′. 22″.

KCR

KCR, or *KTR*... 4° 18′ 47″½ The Angle which the Meridian Line makes with a Line joining the Spire and the Signal of *Kakama*.

1737, *the* 25*th of* May, *in the Morning.*

The Quadrant being in the ſame Situation.

True Time.

At 2ʰ 9′ 38″...*nCS*...45° 36′ 34″½
nCK...19 52 34
KCS...25 44 0½ The Sun's
RCS...30 2 25 Declin. being 20° 55′ 25″.

KTR.. 4 18 24½ The Angle which the Meridian Line makes with a Line joining the Spire of *Torneâ* and the Signal of *Kakama*.

Reducing the Poſition of *Niwa*, given from the former Obſervation, to that of *Kakama*, by the Angle *nTK*, which (pag. 105) is 19° 38′ 17″,8, we ſhall have *KTR* .... 4 18 56 for the Declination of *Kakama*. And taking the Mean of theſe three Obſervations, Fig. 4 and 5.

4° 18′ 24½ } we have 4° 18′ 42″½ for the De-
4 18 47½ } clination of *Kakama* to the
4 18 56 } East.

But we had found from the Calculation of the Triangles, this Angle to be 4° 11′ 53″ to which adding for the Convergence of the Meridians of *Torneå* and *Kittis* (found pag. 122.) 0 7 24
We ſhall have *KTR* . . .=. . . .4 19 17

By the three preceeding Obſervations, it was 4 18 42½
the Difference being 0 0 34½
too ſmall to be looked upon as any real Deviation of the Meridian Line: and accordingly we made no account of it; the rather becauſe the Figure's Poſition had been determined upon *Kittis* by a greater number of Obſervations.

CHAP. III.

Verification of the Distance of Torneå *from* Kittis, *by ten new Series of Triangles.*

I.

BY the Triangles *TnK*, *nKC*, *CKH*, *HCA*, *AHP*, *PHN*, *NPQ*. Fig. 6.

BEGINNING always from the Side *AC*, the Resolution of these Triangles gives for the Distance *QM* . . . . . 54941 toises,
Which differs from 54942,57
found above (pag. 120.) by our first two Series of Triangles, by. . . . $1\frac{1}{2}$

II.

BY the Triangles *TnK*, *KHn*, *nCH*, *HCA*, *APH*, *HNP*, *PNQ*; *QM* = 54936 Fig. 7.
Less than *QM* (pag. 120.) by . . . . . $6\frac{1}{2}$

III.

BY the Triangles *TnK*, *KnH*, *HnA*, *ACH*, Fig. 8.

ACH, HAP, PHN, NPQ; $QM = 54942\frac{1}{2}$
The difference being inſenſible.

IV.

Fig. 9. BY the Triangles *TnK, KCH, HnC, CHA, AHP, PHN, NPQ*; $QM = 54943\frac{1}{2}$
The difference being 1

V.

Fig. 10. BY the Triangles *TnK, KnC, CnA, ACH, HAP, PHN, NPQ*; $QM = 54925$
The difference being . . . . . $17\frac{1}{2}$

VI.

Fig. 11. BY the Triangles *TnK, KnH, HAn, nCA, AHP, PHN, NPQ*; $QM = 54915\frac{1}{2}$
The difference being 27

VII.

Fig. 12. BY the Triangles *TnK, KnC, CAn, nHK, KHN, NHP, PNQ*; $QM = 54912$
The difference being . . . . . $30\frac{1}{2}$

VIII.

Fig. 13. BY the Triangles *TnK, KCn, nAC, CHK, HKN, NHP, PNQ*; $QM = 54906\frac{1}{2}$
The difference being 36

IX.

IX.

BY the Triangles *TnC*, *CnA*, *AnH*, Fig. 14.
HAP, *PHN*, *NPQ*; *QM*. = 54910
The difference being 32½

X.

BY the Triangles *TnC*, *CAn*, *nCK*, *KnH*, Fig. 15.
HKN, *NHP*, *PNQ*; *QM* = 54891½
The difference being . . . . . 51½.

THOUGH the differences arising from so many Series are none of them very considerable, yet we did not think fit to admit them into the Determination of the length of our Arc, but used two others which we judged preferable.

CHAP. IV.

Another Verification of the Distance between Torneå *and* Kittis.

ALTHOUGH from these ten Series, Fig. 16.
it sufficiently appears that no material Error could have crept into our Observations of the Triangles, seeing none of these

Combinations, though ſome of them contain Triangles that might be rejected for the ſmallneſs of their Angles, produce any conſiderable Difference; yet we have added another Verification, which would take off all ſuſpicion of that kind, even though we had obſerved no more than the Angles neceſſary for the firſt Series.

WE ſuppoſe as if we had in two of the Angles of every Triangle, miſtaken by 20″, and by 40″ in the third; and that theſe Errors had always tended to ſhorten the Meridian Line *QM*. The ſmall difference which riſes from this Suppoſition proves the advantage we had from our Triangles being ſo few, and from the Poſition of the Baſe with reſpect to them. The Calculation is after this manner:

BEGINNING always from the Baſe *Bb*, and making the Angles *Bba* and *bBa*, leſs than *BbA* and *bBA* by 20″, you find the Side *aB* inſtead of *AB*. Then making uſe of this Side *aB*, and making the Angles *BaC*, and *aBc*, leſs by 20″ than *BAC*, *ABC*, you find the Point *c* inſtead of *C*, and the Side *ac* inſtead of *AC*.

FROM

FROM *ac*, you find the Sides *ah* and *ch* inſtead of *AH* and *CH*, ſuppoſing the Angles *cah*, *ach*, leſs than *CAH*, *ACH* by 20″ reſpectively. And proceeding ſtill in the ſame manner in diminiſhing the Triangles, you come to have the Figure *qpnhackt* inſtead of *QPNHACKT*.

THEN ſuppoſing likewiſe an Error of 20″ in the Poſition of the Meridian Line, that is, ſuppoſing *pqm* leſs by 20″ than *PQM*, you find after the moſt exact Calculation *qm* leſs than *QM* by no more than 54 toiſes; a difference very inconſiderable to reſult from ſuch a ſtrange Suppoſition of bad Luck and unſkilful Obſervation.

CHAP. V.

Verification of the Amplitude of the Arc of the Meridian.

I.

Observations of the Star α of the Dragon, *made at* Torneå, *in the same place where we had observed δ.*

1737.

THE Plummet cutting the Point of the upper division of the Limb marked 3° 15′, the Micrometer stood at

		Revol.	part.
17 *March.*	Before the Observ. . . .	19	32,7
	In the time of the Obs. .	16	42,0
	After	19	34,0
		19	33,3
		16	42,0
	Difference.	2	35,3

		Revol.	part.
18 *March.*	Before the Obſerv. . . .	22	21,6
	In the time of the Obſ..	19	30,4
	After	22	21,9
		22	21,7
		19	30,4
	Difference	2	35,3
19 *March.*	Before the Obſerv. . . .	21	21,0
	In the time of the Obſ.	18	32,1
	After	21	21,3
		21	21,1
		18	32,1
	Difference	2	33,0

II.

Obſervations of the ſame Star made upon Kittis, *in the ſame place where we had obſerved* δ.

1737.

THE Plummet cutting the Point of the upper Limb that is marked 4° 15′ 0″.

The Micrometer ſtood at

4 *April.*	Before the Obſerv. . . .	21	12,0
	In the time of the Obſ. .	14	43,0
	After	21	12,0
		21	12
		14	43
	Difference	6	13,0

		Revol.	Part.
5 *April.*	Before the Obſerv. . . .	21	12,5
	In the time of the Obſ. .	15	0,0
	After	21	12,2
		21	12,3
		15	0,0
	Difference	6	12,3
6 *April.*	Before the Obſerv. . . .	21	19,5
	In the time of the Obſ. . .	15	7,2
	After	21	19,7
		21	19,6
		15	7,2
	Difference	6	12,4

THESE Obſervations both at *Torneå* and *Kittis*, were made by the Light of a Torch thrown by Reflection upon the Focus of the Teleſcope.

CHAP.

CHAP. VI.

Calculation of the observed Arc of the Meridian.

	Revol.	part.
THE Observations of *Torneâ* give . .	2	35,3
	2	35,3
	2	33,0
And at a Mean . .	2	34,5

Those of *Kittis* give . . .	6	13,0
	6	12,3
	6	12,4
And at a Mean . .	6	12,6

WHENCE we have for the Arc of the Limb which the Plummet cut at the Star's

	Revol.	part.
Passage . . . . . 3° 15′ 0″ —	2	34,5
And for the like Arc upon *Kittis* . . 4 15 0 —	6	12,6

The difference of which two Arcs, that is the difference of the Star's distances from the Zeniths of *Torneå* and *Kittis* is	1°	0′	0″	— 3	Revol. 22,1	part.
But 3 Rev. 22,1 pt.				2′	33″,5	
which subtracted from . . .	1°	0	0			
leaves for the Arc observed . .				57	26,5	
which the Correction on account of the Chord of $5^{\circ}\frac{1}{2}$ its being too small, *viz.*				0°0	0,65	
reduces to				57	25,85	

CHAP. VII.

Verifications of the Sector.

I.

Verification of the whole Arc of $5^{\circ}\frac{1}{2}$.

AT *Torneå*, the 4th of *May*, 1737, we measured upon the Ice of the River a distance of 380 toises, 1 f. 3 inches, 0 line: it was measured twice over; and between the first and second time, there was not the least dif-

difference. At one Extremity of this diſtance was placed the Centre of the Inſtrument, which was laid horizontally upon two great Supports, in a Room we had choſe for that purpoſe, by the River-ſide: at the other Extremity was raiſed a Poſt, with a *Mark* upon it; from whoſe Centre in a Line perpendicular to the firſt meaſured diſtance, which was to ſerve for a Radius, we laid out 36 T. 3 f. 6 in. $6\frac{2}{3}$ lin. for our Tangent, which was terminated at the Centre of a *Mark* fixed upon another Poſt. This formed upon the Ice a Sector of about 380 toiſes Radius, with which we were to compare ours.

FROM the Centre of the Inſtrument we had ſtretched a Silver Wire to a fixt Point, which by trials we had found to be altogether immoveable, ſo as when the Sector turned horizontally upon its Centre, the Wire only not touched its Limb.

THE Angle between the two Marks taken by five different Perſons, exceeded 5° 30′, as follows:

Parts

	Parts of the Microm.
1ſt. by	6,5
2d. by	8,3
3d. by	7,0
4th. by	7,9
5th. by	6,8
Whereof the Mean is	7,3, or $7''$,3.

NOW according to the Conſtruction of the Sector (pag. .) our Arc was too ſmall by $3''\frac{3}{4}$:

whence from	$5^{\circ}\,29'\,56''$,25
taking	7, 3
reſts the true Angle obſerved	5 29 48,95
And the ſame Angle is by Calcul.	5 29 50,00

Which ſhews the exquiſite Conſtruction of this Inſtrument, and what Accuracy may be expected from it. For this difference of $1''$ upon an Arc of $5^{\circ}\frac{1}{4}$, which might come from the Errors in obſerving, is altogether inconſiderable.

II.

II.

Verification of the two Degrees which we used in determining the Amplitude.

THE Sector remaining in the same horizontal Position, we extended from its Centre two small *Wires*, making with each other an Angle very nearly equal to 1°; these Wires only not touched the Limb, and were fixed by two immoveable Pegs: over each of them we placed a Microscope, whose Focus was illuminated by the light of a Wax Candle, collected by a Lens; and as the Micrometer made the Telescope move, all the Points of the Limb passed successively in the Foci of the Microscopes.

IN this manner we compared with the fix'd Interval of the Threads, the two Degrees which we had made use of for the two Stars, making them pass under the threads by turns; and from five Observations made by different Persons, found that the Degree between 1° 37′ 30″, and 2° 37′ 30″, exceeded that between 3° 15′ 0″, and 4° 15′ 0″.

The Excefs was,

By the 1ſt Obſerv. . .	0″,6		
2d	0, 7		
3d	0, 8	}	0″,95
4th	0,85		
5th	1, 8		

WHENCE at a Mean, the Arc uſed for determining the Amplitude by the Star ♪ was greater than that uſed for determining it by α, by 0″,95.

THIS ſmall difference of the two Degrees on the Limb, we ought to reckon upon quite otherwiſe than upon that of the preceeding Article. That depended not only upon the Obſervation of the Point under the thread, but upon the Obſervation of an Object with the Teleſcope; whereas here we had only to place the point exactly under the thread; which, with a Microſcope well lighted, may be performed to the utmoſt nicety.

III.

Verification of the Diviſions of the Sector.

WE examined in the ſame manner every diviſion of the Limb from 15′ to 15′; and have

have marked the result in the following Table, which shews the Exactness both of the Divisions and of the Micrometer.

			according to us. Revol.	part.	*accor. to Mr.* Graham. part.
From	0 15	to 0 30	20	23,2	22,75
	0 30	to 0 45		22,2	22,25
	0 45	to 1 00		23,7	23,5
	1 00	to 1 15		23,4	23,75
	1 15	to 1 30		24,3	24,5
	1 30	to 1 45		23,2	23,5
	1 45	to 2 00		23,8	24,5
	2 00	to 2 15		23,4	23,875
	2 15	to 2 30		23,1	23,5
	2 30	to 2 45		23,6	24,125
	2 45	to 3 00		23,3	23,5
	3 00	to 3 15		24,3	24,375
	3 15	to 3 30		24,0	24,0
	3 30	to 3 45		23,1	23,25
	3 45	to 4 00		24,0	24,125
	4 00	to 4 15		23,4	24,125
	4 15	to 4 30		22,9	23,75
	4 30	to 4 45		23,3	23,5
	4 45	to 5 00		22,9	22,75
	5 00	to 5 15		23,6	24,25
	5 15	to 5 30		23,0	23,625
	5 30	to 5 45		22,1	22,5

The Mean gives 15′ = 20R. 23,3p. .... 23,6p.

CHAP.

CHAP. VIII.

Determination of the Degree of the Meridian which cuts the Polar Circle.

I.

Determination of the Amplitude of the Arc of the Meridian, terminated by the Parallel Circles which pass through Kittis *and* Torneå.

THE Amplitude of the Arc of the Meridian as determined by the Star ♌, was by Observation (p. 136.) . . 57′ 25″,55.

AND the same Amplitude as determined by α, was by Observation . . . 57′ 25″,85.

TO find the true Amplitude which the one and the other of these Stars gives, we must correct the Arcs as follows:

FOR THE STAR ♌.

BY the Precession of the Equinoxes from the 6th of *October* to the 3d of *November*, which

which we take for the Interval of the Obſervations of ♌, this Star was come nearer the Pole by 0″,48 ; and the Star having been to the North of *Kittis*

from the Arc obſerved	57′ 25″,55
ſubtracting this quantity . . .	0,48
there will remain the *Amplitude corrected for the Preceſſion*, viz. . .	57 25,07

BY the Aberration of the Star's Light in the ſame Interval, it was ſeen farther from the Pole by . . . 1,83 which added, gives for the *Amplitude corrected for both the Preceſſion and Aberration* 57 26,9

FOR THE STAR α.

BY the Preceſſion of the Equinoxes from the 18th of *March* to the 5th of *April*, the Interval of the Obſervations of α, this Star was farther from the Pole by 0″,85 ; and having been ſeen to the South of *Torneå*, from the Arc obſerved (p. 152.) *viz.* . . 57′ 25″,85 ſubtracting . . . . . 0, 85 we have for the *Amplitude corrected for the Preceſſion* . . . 57 25,00

BY

BY the Aberration of this Star's light in the ſame time, it appeared nearer the Pole by . . . . . 5″,35
which added, gives for the Amplitude as determined by α, *corrected both for the Preceſſion and the Aberration* . . . 57 30,35

II.

A more exact Determination of the ſame.

Mr. *Bradley* having been pleaſed to ſend me his laſt Diſcoveries upon the Motion of the fixt Stars, as likewiſe Corrections of the two Arcs determined by ♑ and α, not only for the *Preceſſion* of the Equinoxes and *Aberration* of Light, but for that *third Motion* mentioned above; I ſhall here, for the greater accuracy, apply his Corrections as they were ſent me, though they do not ſenſibly differ from thoſe juſt now made.

To the Arc obſerved by ♑ (p. 136.) 57′ 25″,55
add 0 1,38
And you have the Amplitude by ♑ *corrected for all the Motions*, viz. . 57 26,93

To

To the Arc obſerved by α (p. 152.) 57′ 25″,85
add 0 4,57
and you have *the Amplitude by* α,
corrected for all the Motions : . . 57 30 42

THOUGH the difference between theſe two Amplitudes is no more than 3″,49, it appears, from pag. 156, that it is really but 2″,54 : and it would not amount even to 2″, if only the beſt of the Obſervations were uſed ; theſe, where the Micrometer after the Star had paſt the Meridian, upon replaceing the Point under the thread, ſtood at within 1″ or leſs of what it had mark'd before. This difference is ſo ſmall, that there is no doubt left of the Accuracy of the Operations.

I make no allowance for Refraction ; for if there is any at all ſo near the Zenith, it muſt be imperceptible, and cannot effect the preſent Caſe.

III.

Determination of the Degree of the Meridian which cuts the Polar Circle.

WE ſhall then take for the true Amplitude of the Arc of the Meridian between the

Parallels of *Kittis* and *Torneå*, 57′. 28″,67 being a Mean betwixt the two foregoing. And this Amplitude, compared with the length of the Arc $q\mu$, which (*page* 123.) is 55023,47 Toiſes, gives for the *length of the Degree of the Meridian which cuts the Polar Circle* 57437,9 *Toiſes*.

IV.

Remark upon the Degree meaſured by M. Picard.

THIS Degree is longer by 377,9 than that which paſſes commonly for the Mean Degree of *France*, rated by M. *Picard* at 57060 Toiſes. But if M. *Picard*'s Degree is corrected by making the proper Allowances, firſt for the *Aberration* of Light of the Star δ in *Caſſiopeia*'s *Knee*, by which he determined his Amplitude, taking for the middle times of his Obſervations the 15th of *September*, and the 15th of *October*, there will be, on this account, $8''\frac{1}{2}$ to be added to the Amplitude of the Arc between *Malvoiſine* and *Amiens*. And if there is further added $1''\frac{1}{2}$ for the *Preceſſion* of the Equinoxes, and $1''\frac{1}{4}$ for the *Refraction*, all which he had neglected, his Amplitude will become

1°.

$1^{\circ}.23'.6''\frac{1}{2}$. And comparing it with his Arc of 78850 Toiſes, the Degree of the Meridian near *Paris* will be 56925,7 Toiſes, ſhort of ours by 512,2.

IN fine, If Mr. *Bradley*'s Theory is ſet aſide, and the Stars are ſuppoſed to have no other Change of Declination but what ariſes from the Preceſſion of the Eqinoxes, our Amplitude by the Star δ (*page* 159.) would be 57'.25",07, and by the Star α (*ibid.*) 57'.25",00. Whence our Degree would be ſtill longer than it is in Mr. *Bradley*'s Hypotheſis.

V.

CONCLUSION.

THE Degree of the Meridian which cuts the Polar Circle being longer than a Degree of the Meridian in France, *the Earth is a Spheroid flatted towards the Poles.*

CHAP. IX.

A Method to determine the Figure of the Earth from the Lengths of two Degrees of the Meridian.

IF the Length of two different Degrees of the Meridian is measured at two different places of known Latitudes, the Figure of the Earth may be determined: Of which Problem you have the following Solution; with a Formula expressing the Proportion of the Earth's Axis to the Diameter of the Equator.

Problem.

The Lengths and Latitudes of two Degrees of the Meridian being given, to find the Figure of the Earth.

Fig. 17. Considering the Earth as a Solid generated by the Revolution of an *Ellipse* upon its Axis, from which it very little differs, let the Ellipse PAp represent a Meridian, whose Axis is Pp, and the Diameter of the Equator

Equator $A\,a$. Let $E\,e$, $F\,f$, be two Degrees of this Ellipſe, or two little Arcs of the ſame Amplitude. The Perpendiculars to the Ellipſe at their Extremities will meet at points G and H, making the Angles at G and H equal. And the Latitudes of theſe two Arcs, or the Angles EKA, FLA are given.

LET CP be to CA as m to 1; $CM = x$, $EM = y$; the Sine of the Angle EKA, that is the Sine of the Latitude of the point E, $= f$: The Sine of FLA, or of the Latitude of F, $= s$, and the Radius 1. Put likewiſe the Arcs $Ee = E$, and $Ff = F$.

BY the Property of the Ellipſe $y = m \times \sqrt{1 - x^2}$; $EK = m \times \sqrt{1 - x^2 + m^2 x^2}$; and the Radius of Curvature $EG = \frac{1}{m} \times \overline{1 - x^2 + m^2 x^2}\,|^{\frac{3}{2}}$ and the Expreſſions of FL and FH are the ſame for their correſpondent x's. Now the Sine of EKA, to the Radius 1, being f, $1 : f :: m\sqrt{1 - x^2 + m^2 x^2} : m\sqrt{1 - x^2}$, that is $x^2 = \frac{1 - ff}{1 - ff + m^2 f^2}$. Subſtituting this Value of x^2 in the Expreſſions of EG and FH,

FH, we have $EG = \frac{m^2}{1 - f^2 + m^2 f^2 |^{\frac{3}{2}}}$ and $FH = \frac{m^2}{1 - s^2 + m^2 s^2 |^{\frac{3}{2}}}$ And seeing the Arcs Ee, and Ff are of the same Amplitude, that is, seeing the Angles G and H are equal, $E : F :: \frac{m^2}{1 - f^2 + m^2 f^2 |^{\frac{3}{2}}} : \frac{m^2}{1 - s^2 + m^2 s^2 |^{\frac{3}{2}}}$ that is,

$$\overline{E \times 1 + m^2 - 1 \times f^2 |^{\frac{3}{2}}} = \overline{F \times 1 + m^2 - 1 \times s^2 |^{\frac{3}{2}}}$$

Or, by extracting the Root,

$$E \times \overline{1 + \tfrac{3}{2} \times m^2 - 1 |} \times f^2 + \tfrac{3}{8} \times \overline{m^2 - 1 |^2} \times f^4 + \&c. = F \times \overline{1 + \tfrac{3}{2} \times m^2 - 1 |} \times s^2 + \tfrac{3}{8} \times \overline{m^2 - 1 |^2} \times s^4 + \&c.$$

BUT the Spheroid of the Earth being very little different from a Sphere, the quantity $m^2 - 1$ is small, and the Terms multiplied by its Square and its higher Powers may be neglected. Whence $E \times \overline{1 + \frac{3}{2} \times m^2 - 1} \times f^2 = F \times \overline{1 + \frac{3}{2} \times m^2 - 1} \times s^2$ that is,

$$2E + 3 \times m^2 - 1 \times E f^2 =$$

$2F + 3 \times \overline{m^2 - 1} \times Fs^2$. Or $1 - m^2 = \frac{2 \times E - F}{3 \times Ef^2 - Fs^2}$ Or putting D for the difference between the Semi-axe and the Semi-diameter of the Equator, it is $D = \frac{E - F}{3 \times Ef^2 - Fs^2}$ or $D = \frac{E - F}{3E \times \overline{f^2 - s^2}}$ Whence the Species of the Spheroid may be easily determined, and a Table calculated of the Lengths of a Degree for every Latitude.

Coroll. IF one of the Degrees is taken at the Equator, the Equation is changed into $D = \frac{E - F}{3Ef^2}$ And if the other Degree is taken at the Pole, it is $D = \frac{E - F}{3E}$ Whence it follows, That the Semi-Diameter of the Equator is to thrice the last Degree of Latitude, as the difference between the Semi-Diameter of the Equator and the Semi-Axis is to the difference between the first and the last Degree of Latitude.

OBSERVATIONS

Made at the Polar Circle.

BOOK II.

Containing Aſtronomical Obſervations for determining the Height of the Pole at Torneå, *the Refraction, and the Longitude.*

CHAP. I.

Obſervations of Arcturus, *and of the Pole-Star, at* Torneå *and at* Paris.

I.

Obſervations of Arcturus, *and the Pole-Star, at* Torneå.

WE obſerved the diſtances of the Pole-Star, and of *Arcturus* from the Zenith, at *Torneå* and *Paris*, in order to diſcover if, at the height of theſe Stars, the Refraction at *Torneå* was ſenſibly different from

from what it is at *Paris*; as the Obſervations of *Bilberg* at *Torneå*, and of the *Hollanders* in *Nova Zembla* gave ground to think.

WE had choſe theſe two Stars, becauſe the Arc of the Meridian terminated by their Parallels, was, at *Torneå*, nearly of the ſame height as at *Paris*, only in an oppoſite Situation. Whence, if the Refraction was greater at *Torneå*, this Arc muſt there appear ſhorter than at *Paris*.

BUT it is found by Obſervation to be very near of the ſame quantity at both theſe places. The little difference there was, made rather for leſſening the Refraction at *Torneå*; but this we aſcribe to the Errors of the Obſervations, which were not of Authority enough to eſtabliſh an Inequality of Refraction, at that height.

FOLLOW the Obſervations of theſe two Stars, made at *Torneå* with a Quadrant of three foot Radius, and at *Paris* with one of $2\frac{1}{2}$; both well verified by back Obſervations.

Diſtance

Diſtance of the Pole-Star from the Zenith of Torneå.

Obſerved in *Novem.* and *Decem.* 1736. Reduced for 1737.

	°	′	″	°	′	″
27 Novemb. . .	22	2	51	22	3	11
29 Novemb. . .	22	2	40	22	3	0
1 Decemb. . .	22	2	43	22	3	3

Whence, at a Mean, the diſtance of the Pole-Star from the Zenith of *Torneå*, in the beginning of *December* 1737, 22 3 5

Diſtance of Arcturus *from the Zenith of* Torneå.

1736	°	′	″	°	′	″
26 Novemb. . .	45	15	49	45	16	6
1 Decemb. . .	45	16	4	45	16	21
3 Decemb. . .	45	15	43	45	16	0
9 Decemb. . .	45	15	52½	45	16	9½

Whence

Whence at a Mean, the diſtance of *Arcturus* from the Zenith of *Torneå* was, in the beginning of *December* 1737,	45	16	9
Which added to the diſtance of the Zenith from the Pole-Star	22	3	5
Gives for the Arc of the Meridian terminated by the Parallels of theſe two Stars, as obſerved at *Torneå*, ...	67	19	4

II.

Obſervations of the ſame Stars at Paris.

Diſtance of the Pole-Star from the Zenith of Paris.

Obſerved in *Novemb.* and *Decemb.* 1737.

	°	′	″
8 Novemb.	39	2	19½
9 Novemb.	39	2	22
5 Decemb.	39	2	30
8 Decemb.	39	2	33
14 Decemb.	39	2	34

Whence

Whence at a Mean, the diſtance of the Pole-Star from the Zenith of *Paris* was, in the beginning of *December* 1737, ... 39° 2′ 8″

Diſtance of Arcturus *from the Zenith of* Paris.

	°	′	″
29 October 1737	28	16	30
8 November	28	16	32
16 December	28	16	44
24 December	28	16	43

Whence, at a Mean, the diſtance of *Arcturus* from the Zenith of *Paris* was, in the beginning of *December* 1737, 28 16 37

Which added to the diſtance of the Zenith from the Pole-Star 39 2 28

Gives the Arc of the Meridian terminated by the Parallels of theſe two Stars, as obſerved at *Paris*, ... 67 19 5

III. *The*

III.

The ſame repeated, upon Obſervations of the Pole-Star in the lowermoſt point of its Circle.

Diſtances of the Pole-Star from the Zenith of Tornea.

Obſerved in *Nov.* and *Decemb.* 1736.	Reduced for 1737.
26 Novemb. . . . 26° 14′ 37″	26° 14′ 17″
27 Novemb. . . . 26 14 37	26 14 17
1 Decemb. . . . 26 14 36	26 14 16

Whence at a Mean, the diſtance of the Pole-Star from the Zenith of *Torneå* was, in the beginning of *December* 1737, ... 26 14 17

The diſtance of *Arcturus* (*page* 171.) was 45 16 9

Whence the Arc of the Meridian terminated by the Parallels of theſe two Stars, as obſerved at *Torneå*, is 71 30 26

IV. *Di-*

IV.

Diſtances of the Pole-Star from the Zenith of Paris.

Obſerved in *Novem.* and *Decem.* 1737.

	°	′	″
2 Decemb.	43	13	42
3 Decemb.	43	13	41
9 Decemb.	43	13	42
14 Decemb.	43	13	47
19 Decemb.	43	13	45
Whence at a Mean, the diſtance of the Pole-Star from the Zenith of *Paris* was, in the beginning of *December* 1737, ...	43	13	43
The diſtance of *Arcturus* (*p.* 172.)	28	16	37
Whence the Arc of the Meridian terminated by the Parallels of theſe two Stars as obſerved at *Paris*, is	71	30	20

V.

FROM which Obſervations it appears, that at the height of theſe Stars, the Refractions

fractions at *Torneå* and at *Paris* are not ſenſibly different.

BUT, independent of theſe Obſervations, we may firſt ſeek the height of the Pole at *Torneå*, ſuppoſing theſe Refractions to be equal, which at this height can cauſe no ſenſible Error; and then make uſe of the height of the Pole thus determined, to find the horizontal Refractions; which if they come out nearly the ſame as at *Paris*, we may thenceforth ſafely enough uſe the ſame Table of Refraction for the greateſt Altitudes at *Torneå*.

CHAP. II.

Height of the Pole at Torneå.

I.

Height of the Pole, from Obſervations made with the Quadrant of three foot Radius.

IN the beginning of *December* 1736, the leaſt diſtance of the Pole-Star from the Zenith of *Torneå* was (*page* 170.) 22° 2′ 45″
the greateſt (*page* 173.) 26 14 37
Their Sum . . . 48 17 22
Whoſe half . . . 24 8 41
is the diſtance of the Zenith of *Torneå* from the Pole,
and its Compliment 65 51 19
will be the apparent height of the Pole. From which ſubtracting a Mean between the Refractions at *Paris*, as determined by Mr. *Caſſini* and Mr. *de la Hire*, viz. . . 0 0 29
there remains 65 50 50
for the height of the Pole at *Torneå*, that is for the ſouthermoſt point of the Arc which we meaſured.

II. *Height*

II.

Height of the Pole, from Obſervations made in the ſame Place with a Quadrant of two foot Radius.

The greateſt diſtance of the Pole-Star from the Zenith.	*The leaſt diſtance of the Pole-Star from the Zenith.*
At *Torneå* 1737.	
° ′ ″	° ′ ″
6 Jan. . . 26 14 21	9 Jan. . . 22 3 2
7 Jan. . . 26 14 24	12 Jan. . . 22 2 57
	18 Jan. . . 22 2 54
	19 Jan. . . 22 3 0
This day the Quadrant had been verified by back-Obſervation.	22 Jan. . . 22 2 57
The *Means* 26 14 22½	22 2 58
Sum of theſe diſtances	48 17 20
whoſe half	24 8 40
is the diſtance of the Zenith of *Torneå* from the Pole, whoſe Complement	65 51 20
is the apparent height of the Pole; from which taking for the Refraction	0 0 29
remains the height of the Pole at *Torneå*	65 50 51

III.

A Remark.

ALTHOUGH theſe heights of the Pole in the two laſt Articles coincide, yet you may obſerve there is a difference of 14″ in the diſtance of the Pole-Star from the Pole, as there marked. Which makes me ſuſpect there have been ſome Errors in the Obſervations that have compenſated each other. This might be partly cauſed too, by the Preceſſion of the Equinoxes and the *Aberration* of Light, in the interval of the Obſervations.

WE may then take for the height of the Pole at *Torneå* . . . . . 65°. 50′. 50″. exceeding what *Bilberg* found it to be by 8′, and by 11′ what he ought to have found it, if he had made the proper Allowances for the obliquity of the *Ecliptic*, the *Parallax*, and *Refraction*.

AND ſeeing his Obſervations gave him an Altitude of the Pole ſo wide of the Truth, we need not wonder that he fell into ſtill greater Errors as to the *Refraction*; which

which has hitherto been imagined to be almoſt the double of what it is at *Paris*.

THE Amplitude of our Arc between *Torneå* and *Kittis* being (*p.* 162.) 57′ 28″,7
the height of the Pole upon *Kittis* will be 66 48 18,7
for which we ſhall take . . . 66 48 20

CHAP. III.

Meridian Altitudes of the Sun.

I.

Meridian Altitudes of the upper Limb of the Sun, obſerved at Torneå, *at the extremity of our Meridian Line, with a Quadrant of three foot Radius*, 1736.

WE placed, in a little Obſervatory built on the River, the Inſtrument we had made uſe of at *Kittis* to determine the poſition of our Triangles with reſpect to the Meridian Line, (*vid.* p. 109.)

THE Teleſcope of this Inſtrument moved about its Axis, exactly in the Plane of the Meridian; and if it chanced to be put out of this poſition, we reſtored it by means of an Object placed at about half a League's diſtance in the Meridian Line. The Altitudes were taken in the Moment the Sun paſt the Centre of this Teleſcope.

	°	′	″
26 November 1736.	3	35	23
27 November	3	24	30
1 December	2	45	42
3 December	2	31	0
8 December	1	56	51

II.

Meridian Altitudes of the Upper Limb of the Sun obſerved in the ſame place, with a Quadrant of two foot Radius, 1737.

	°	′	″
5 January 1737	2	9	32
7 January	2	24	33
9 January	2	37	26
12 January	3	4	26
13 January	3	15	23
19 January	3	21	29

ON the 22d the Quadrant was verified by back-Obſervation, and afterwards uſed to take the horizontal Angles.

III.

Meridian Altitudes of the Sun's upper Limb at the vernal Equinox.

WE verified once more the Quadrant of three foot, and obſerved the following Meridian Altitudes of the upper Limb of the Sun.

15 March 1737 . . .	22°	26′	16″
16 March	22	50	12
17 March	23	13	50
18 March	23	37	9
21 March	24	47	11
22 March	24	11	35

CHAP. IV.

Determination of the Refractions.

I.

THE following Calculation ſuppoſes the height of the Pole, as found p.

THE finding the Refraction by the Meridian Altitudes of the Sun ſuppoſes likewiſe, to be given, the *Elevation of the Equator*, *the Obliquity of the Ecliptic*, *the Sun's Place*, *and his Parallax*.

I put the Elevation of the

	°	′	″
Equator	24	9	10
the Obliquity of the *Ecliptic* . .	23	28	20

the Parallax according to Mr. *Caſſini*; and the Sun's place, from Mr. *de Louville*'s Tables, reduced to the Meridian of *Torneå*, which we know to be nearly 1ʰ. 23′ Eaſt of *Paris*. And an Error of a few Minutes can here be of no conſequence, becauſe, at the time of our Obſervations, the Sun's daily

daily Change of Declination is inconsiderable.

II.

The 1st of Decemb. 1736, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	21	55	21
The Eelvation of the Equator .	24	9	10
Whence the height of the Sun's Centre	2	13	49
The Parallax to be subtracted .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå* . .	2	13	39
The Sun's Semi-diameter to be added	0	16	19
Gives the true height of the Sun's upper Limb	2	29	58
But the same height was by Observation	2	45	42
Whence the Refraction at the apparent height of 2°. 46′. is	0	15	44

III.

The 3d of Decemb. 1736, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	22	12	46
The Elevation of the Equator .	24	9	10
Whence the height of the Sun's Centre	1	56	24
The Parallax to be ſubtracted .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå* . . .	1	56	14
The Sun's Semi-diameter to be added	0	16	20
Gives the true height of the Sun's upper Limb	2	12	34
But the ſame height was by Obſervation	2	31	0
Whence the Refraction at the apparent height of 2°. 31′. .	0	18	26

IV. *The*

IV.

The 8th of Decemb. 1736, *at Noon.*

	° ′ ″
The South Declination of the Sun at *Torneå*	22 48 33
The Elevation of the Equator .	24 9 10
Whence the height of the Sun's Centre	1 20 37
The Parallax to be ſubtracted . .	0 0 10
Leaves the true height of the Sun's Centre at *Torneå*	1 20 27
The Sun's Semi-diameter to be added	0 16 21
Gives the true height of the Sun's upper Limb	1 36 48
But the ſame height was by Obſervation	1 56 51
Whence the Refraction at the apparent height of 1°. 57′. . .	0 20 3

V. *The*

V.

The 5th of January 1737, *at Noon.*

	°	′	″
The South Declination of the Sun at *Torneå*	22	35	53
The Elevation of the Equator .	24	9	10
Whence the height of the Sun's Centre	1	33	17
The Parallax to be ſubtracted . .	0	0	10
Leaves the true height of the Sun's Centre at *Torneå*	1	33	7
The Sun's Semi-diameter to be added	0	16	22
Gives the true height of the Sun's upper Limb	1	49	29
But the ſame height was by Obſervation	2	9	32
Whence the Refraction at the apparent height of 2°. 9′½ . .	0	20	3

VI.

WE have here choſe the leaſt Altitudes of the Sun, to calculate the Refractions, and compare them with thoſe at *Paris* for the

the ſame Altitudes, according to Meſſrs *Caſſini* and *de la Hire*; and do not find thoſe of *Torneå* ſo much different as to infer an Inequality of Refraction at *Torneå*, and at *Paris*.

AND if the Refractions are very much leſs at the Equator than at *Paris*, we may at leaſt be very ſure that their Increaſe from *Paris* to the *Polar Circle* is very inconſiderable; contrary to what has been hitherto thought, that they were twice as great at *Torneå* as at *Paris*.

CHAP.

CHAP. V.

Determination of the Refractions upon Kittis *by* Venus Inoccidua.

I.

WE have farther, upon this Subject, some singular enough Observations upon the Planet *Venus*, which for two Months together appeared always above our Horizon. We observed her first at *Kittis* with the Quadrant of 3 f. Radius, well verified.

Meridian Altitudes of Venus *upon* Kittis.

	Corrected by the Parallax.
To the North.	° ′ ″ ° ′ ″
5th *April* 1737, in the Morn.	0 58 6 . . . . . 0 58 21
6th	1 11 44 . . . . . 1 11 59
7th	1 25 5 . . . . . 1 25 20

To the South.	*Corrected by the Refraction and Parallax.*
6th *April* 1737, in the Even.	47 17 54 . . . . . 47 17 3
7th	47 32 45 . . . . . 47 31 54
Diurnal Motion in Declination	14 51

WE

WE corrected the Altitudes of *Venus*, that were obſerved to the South, by both Refraction and Parallax, putting 15″ for her horizontal Parallax in the diſtance ſhe then was from the Earth.

II.

Calculation of the Refractions upon Kittis, *from the Obſervations of* Venus.

Height of the Pole upon *Kittis* (p. 179.)	66°	48′	20″
Elevation of the Equator . .	23	11	40
Meridian Altitude of *Venus*, the 6th of *April* in the Evening . .	47	17	3
North Declination of *Venus* . .	24	5	23
Diſtance of *Venus* from the Pole, the 6th of *April* in the Evening	65	54	37
Meridian Altitude of *Venus*, the 7th of *April* in the Evening . .	47	31	54
North Declination of *Venus* . .	24	20	14
Diſtance of *Venus* from the Pole, 7th *April* in the Evening . . .	65	39	46

Whence the Diſtance of *Venus* from the Pole, when ſhe paſt the Meridian to the North, on the

7th

7th of *April* in the Morning, was	65	47	11½
And conſequently her true Altitude	1	1	8½
The Meridian Altitude of *Venus*, the 7th of *April* in the Morning, as obſerved and corrected by the Parallax, was	1	25	20
Whence the Refraction at the Altitude 1° 25′ is		24	11½

CHAP. VI.

The like Operations at Torneå.

I.

WE continued at *Torneå* our Obſervations of this Planet, having for that purpoſe verified the Quadrant of 2 foot.

Meridian Altitudes of Venus.

To the South.	*Corrected by the Refraction and Parallax.*
28th *April* 1737, in the Even.	51 36 3 . . . . . 51 35 20
29th	51 38 50 . . . . . 51 38 7
30th	51 41 47 . . . . . 51 41 4

To

To the North.		*Corrected by the Parallax.*
	° ′ ″	° ′ ″
30th of *April* . . .	3 34 58	3 35 14
1st of *May* . . .	3 38 5	3 38 21

II.

Calculation of the Refractions at Torneå, *by the Observations of* Venus.

	° ′ ″
Elevation of the Equator at *Torneå*	24 9 10
Meridian Altitude of ♀ the 28th of *April*	51 35 20
North Declination of ♀ . .	27 26 10
Distance of ♀ from the Pole, 28th of *April* . . .	62 33 50
Meridian Altitude of ♀, the 29th of *April*	51 38 7
North Declination of ♀ . .	27 28 57
Distance of ♀ from the Pole . .	62 31 3
Diurnal Motion in Declination, from the 28th to 29th *April* . .	0 2 47
Meridian Altitude of ♀, the 30th of *April*	51 41 4
North Decl. of ♀	27 31 54
Distance of ♀ from the Pole .	62 28 6

		°	′	″
Diurnal Motion of Declination, from the 29th to 30th *April* . .		0	2	57
The Mean of theſe diurnal Motions		0	2	52
Whereof one half for 12 hours is		0	1	26
Diſtance of *Venus* from the Pole, the 30th of *April*, *P. M.* . .		62	28	6
Whence the Diſtance of *Venus* from the Pole, when ſhe paſt the Meridian, the 30th of *April* in the Morning		62	29	32
and on the 1ſt of *May* in the Morning		62	26	40
Whence her true Height	30th *April*, *A. M.*	3	21	18
	1ſt of *May*, *A. M.*	3	24	10
Merid. Alt. of ♀, as obſerved and corrected by the Parallax.	30th *April*, *A. M.*	3	35	14
	1ſt of *May*, *A. M.*	3	38	21
Whence the Refract. at the Altitude . .	$3^{\circ}\ 35'$ . . .	0	13	56
	3 38 . . .	0	14	11

CHAP.

CHAP. VII.

Concerning the Longitude of Torneå.

I.

WE could make no uſe of *Jupiter's Satellites*, becauſe at the time we might have obſerved him, he was too near the Horizon, and always hid in Vapour.

WE endeavoured therefore to determine this Longitude by ſome other Obſervations; from which, as here ſet down, it may be found out, provided correſpondent Obſervations have been made in any Place, whoſe Longitude is known.

Eclipſes of fix'd Stars, by the Moon.

The 12th of December, 1736, P. M.

Time by the Clock.

h	′	″		
11	15	4	*Aldebaran*	Tranſits obſerved with the Teleſcope moveable on an Axis, in the Plane of the Meridian.
11	56	2	*Rigel* . . .	
11	46	12½	an Occultation of the	

Star μ in the *Linum* of *Piſces*, which gives $11^h\ 29'\ 58''$ *true Time.*

AS the Sun rarely appeared, being at Noon leſs than a Degree above the Horizon, we calculated the Hour by comparing his *Right Aſcenſion* with that of the Stars *Aldebaran* and *Rigel.*

The 12th of January, 1737, P. M.

True Time.

$6^h\ 4'\ 30''$ an Occultation of γ of *Taurus.*

$10\ 57\ 58$ an Occultation of the Northermoſt of the two Stars of *Taurus*, called ϑ.

The 13th of January, 1737, A. M.

$3^h\ 14'\ 20''$ an Emerſion of *Aldebaran.*

WE found the Hour by Obſervations of the Sun in the Meridian, taken the 12th and 13th of *January.*

The 11th of March, 1737, P. M.

True Time.

$7^h\ 35'\ 9''$ an Occultation of λ in *Gemini.*

II.

A Horizontal Eclipſe of the Moon.

The 16*th of* March, 1737, P. M.

True Time.	Quantity of the Eclipſe.	
$6^h\ 23'\ 55''$	$5^{dig.}\ 0'$	
25 30		*Promontorium acutum* is diſcover'd.
28 0	4 56	
28 30		The Shadow touches the *Mare humorum*.
35 0	4 0	
39 30	3 29	
40 20		The Shadow touches *Langrenus*.
43 40		*Tycho* half diſcovered.
47 0		*Mare Nectaris* out of the Shadow.
47 30	2 37	
49 15	2 21	
51 45	2 7	
53 35	1 56	
7 2 10		End of the Eclipſe, with a Teleſcope of 7 foot.
2 35		End of the Eclipſe, with 2 Reflecting Teleſcopes of 15 Inches.
2 50		

III.

WE have one Obſervation more of a Star eclipſed by the *Moon*, taken upon one of our Mountains.

The 2d of Auguſt, 1736, A. M. *upon* Pullingi.

A little before the Obſervation, we compared two exceeding good Watches.

$5^h\,36'\ 0''\frac{1}{2}$ by the Watch R
$5\ 26\ 15$ by the Watch G } diff. $9'\,44''\frac{1}{2}$

At $5^h\,46'\,42''$ on the Watch R, an Immerſion of *Aldebaran*, in the enlightned Diſk of the Moon.

The Watches compared. $\left\{\begin{matrix}5^h\,49'\ 0''\ R\\ 5\ 39\ 15\ G\end{matrix}\right\}$ differ... $9'\,45''$

Heights of the upper Limb of the Sun in the Eaſt, with the Quadrant of 2 foot.

$R...5^h\,59'\,14''$ $G...5\ 49\ 22$	$16°\,20'\,0$
$R...6\ 4\ 16\frac{1}{2}$ $G...5\ 54\ 30\frac{1}{2}$	$16\ 50\ 0$
$R...6\ 9\ 20$ $G...5\ 59\ 32$	$17\ 20\ 0$

Meridian Altitudes of the upper Limb of the Sun.

The 1ſt of *Auguſt* . . .	$41°\,35'\,10''$
2d	$41\ 20\ 0$

FROM

FROM theſe Obſervations we concluded, that the Immerſion of *Aldebaran* happened at $5^h\ 45'\ 0''$, true Time.

To find the Longitude of *Torneå*, you may likewiſe make uſe of the Obſervations of the Sun at the Equinox, (p. 181.) We have in our Calculations put it at $1^h\ 23'$ Eaſt of *Paris*. It may be more accurately fixt when the correſpondent Obſervations are got, and all of them compared together.

CHAP. VIII.

The Declination of the Magnetic Needle.

THIS Obſervation we made with a Braſs Compaſs, 10 Inches in diameter, by looking through its Sights at an Object placed in the Meridian Line of our little Obſervatory upon the River. And the Mean of our Obſervations with four different

Needles, gave us for the Declination at *Torneå* in the Year 1737, 5° 5′ Weſt.

Mr. *Bilberg*, in 1695, had found it 7°, Weſt likewiſe.

BOOK III.

The Measure of Gravitation at the Polar Circle.

CHAP. I.

Of Gravitation in general.

WHATEVER be the Cause of *Gravitation*, we may conceive it as a Force inherent in Bodies, whereby they are animated, as it were, and urged to fall towards the Earth; and upon comparing the Effects of this Force, when it makes a Stone fall to the ground, with what it must be to keep the Moon in her Orbit, we shall find by Calculation, that the Gravitation which acts here upon the Earth, extends to the Region of the Moon, and regulates her Motion. As the Power which makes Bodies fall downwards, likewise retains the Moon in

her Orbit, as ſhe circles round the Earth; we are led by Analogy to think, that every Planet, and the Sun himſelf, has each its Gravitation, producing the like effects: and that what the Moon is to the Earth, that is the Earth it ſelf, and every other Planet, to the Sun. A Gravitation towards the Sun may poſſibly be the Power that keeps them in their Orbits. And indeed the Motion of the heavenly Bodies perfectly correſponds to this univerſal Law. Such are the Effects of Gravitation in the Heavens.

IT would be going too far to mention all its Effects here on Earth. It is This that preſides almoſt in every Phyſical Operation; and while the greateſt part of Machines are contrived to overcome it, it is the Agent that gives motion to the reſt.

IF we are ignorant of the Cauſe of *Gravitation*, as probably we muſt ever be; we know however one of its moſt eſſential Properties; that it is diffuſed through all Bodies in proportion to their quantities of Matter; each Particle of the Body ſharing an equal portion of whatever Cauſe it is that makes it fall.

HERE

HERE we muſt carefully diſtinguiſh between the *Gravitation* of a Body, and its *Weight*. *Gravitation* is that Force, conceived as diſtinct from the Body, which animates and urges every one of its parts to fall; whence it happens, that, abſtracting from the reſiſtance which the Air makes to falling Bodies, a great Body falls juſt as ſoon, and no ſooner, than the ſmalleſt of its parts, if it were detach'd from it, and fell alone from the ſame height.

GRAVITATION in a great Body is no greater than in a ſmall. The Caſe is different as to Weight; *that* depends not only upon *Gravitation*, but likewiſe upon the quantity of Matter of the Body. The *Weight* increaſes in proportion to the Body; it is the product of the Gravitation and the quantity of Matter.

BUT is *Gravitation* the ſame all the Earth over? Will it every where make Bodies fall from the ſame height in the ſame time? A very little attention ſerves to ſhew, that this Queſtion is not to be reſolved by weighing one and the ſame Body in different places.

In

In the place you carry it to, Gravitation will equally affect the Body it ſelf and the Weights you compare it with: And that which weighed a Pound at *Paris*, will weigh the ſame any where elſe.

BUT a Pendulum that ſwings freely, whether ſuſpended by a Thread, or by an inflexible Rod, moves with a determinate Velocity which depends on the length of the Pendulum, and the Force of Gravitation together. And if trial is made with ſuch a Pendulum, keeping its length exactly the ſame in the different places, there can no difference happen in the velocity of its Vibrations, but from a difference of Gravitation. For the different Denſity or Elaſticity of the Air will here produce no ſenſible effect; eſpecially if the degree of Heat in the Countries where the Experiments are made is the ſame, which is exactly enough known by a Thermometer. If, in the Country where the Pendulum ſhould be carried, the Gravitation ſhould be greater, its Vibrations would be quicker; and if it was leſs, they would be more ſlow. This laſt is that Phenomenon which was firſt taken notice of by Mr. *Richer*, in the Iſland of *Cayenne*; and one

one of the nobleſt Diſcoveries in Natural Philoſophy it is. Bodies were found to weigh leſs at *Cayenne* than at *Paris*; and ſoon after a very probable Cauſe of this Phenomenon was aſſigned.

ALL Bodies that have a circular Motion make a continual Effort to recede from the Center. This Effort ariſes from a certain Force there is in Matter, whereby it endeavours to continue in its preſent State, whether of Reſt or Motion. Now as a Body revolving in a Circle deſcribes in every Inſtant a Particle of the Circumference, which may be conſidered as a Right Line, it muſt in every Inſtant be making an effort to go on in the direction of that Right Line; and from this Effort is produced what is called the Body's *Centrifugal Force*.

IF the Earth then revolves about its Axis, each of its Parts endeavours to recede from its Centre of Motion; and the greater the Circle is which the Part deſcribes, that is, the nearer it is to the Equator, the greater will this Effort be; and as it tends to throw off Bodies from the Earth, that is, as its Direction is oppoſite to that of Gravitation, it muſt deſtroy

deſtroy ſome part of it; and ſo much the more, as the Body is near the Equator. If therefore the *Primitive Gravitation*, which I ſhall call *Gravity*, to diſtinguiſh it from Gravitation as diminiſhed by the Centrifugal Force; if, I ſay, Gravity were abſolutely equal every where, yet the actual Gravitation of a Body muſt be leſs towards the Equator, and increaſe towards the Poles; where at laſt it ſuffers no more any diminution from the Centrifugal Force, becauſe the Poles are no wiſe affected by the Earth's Revolution round its Axis.

THIS Theory of Gravitation is extremely probable, and has been confirmed by all the Experiments that have been made near the Equator.

YET, before our Journey to the North, it was not perhaps abſolutely ſure that Gravitation was thus regularly diminiſhed in going towards the Equator, although the Obſervations made in *America* all gave ſome diminution. The phyſical Cauſe of Gravitation being unknown, it might ſtill be doubted whether the diminution obſerved was owing to the primitive Gravity its being im-

impaired by the Centrifugal Force, or whether it might not have ſome particular Cauſe combined with the Centrifugal Force: it might even be queſtioned whether the primitive Gravity itſelf was not ſubject to regular, or perhaps irregular Variations. The rather, that ſome Experiments made by able enough Artiſts, ſeemed to give colour to theſe Suſpicions. Mr. *Picard* had not found his Second-Pendulum longer in *Denmark* than at *Paris*, nor even longer than in the Southermoſt Parts of *France*.

IN ſhort, hitherto the only Proof of this Diminution was from Experiments made, towards the Equator indeed, but in places too little diſtant from each other to found an unexceptionable Proof.

IT were to be wiſhed that trial were made in the *Eaſt-Indies*, at the Latitudes of *Cayenne*, *S. Domingo*, and *Jamaica*, whether the diminution was there the ſame as in *America*. But nothing could be more proper for the deciſion of this important Point, and for Natural Philoſophy in general, than the obſerving the Gravitation of Bodies in the moſt Northern Countries, eſpecially after the

the Doubts that M. *Picard*'s Experiments in *Denmark* had raiſed.

LET it ſtill be remembred what diſtinction I make between *Gravity* and *Gravitation*. *Gravity* is that Force whereby a Body would fall to the Earth, ſuppoſed at reſt: *Gravitation* is the ſame Force, but diminiſhed by the *Centrifugal*. 'Tis only this laſt, diminiſhed, and confounded with the Centrifugal, which we can meaſure by our Experiments; but if we are well acquainted with it, we may come at laſt to diſtinguiſh what of the Primitive Gravity remains, and what has been deſtroyed by the Centrifugal Force.

HITHERTO this Subject has been enquired into with no other view than to determine the Figure of the Earth from the Equilibration of its parts. But the Theory of Gravity ſerves to much greater purpoſes than this Determination.

IF the Primitive Gravity were known, it would not only determine the Figure of the Earth, but demonſtrate its Motion round its Axis.

ON

ON the other hand, if we take the Motion of the Earth for granted, as I believe there is at preſent no Philoſopher that calls it in queſtion; and if its Figure is otherwiſe known, the different Gravitations will diſcover the quantity of primitive Gravity in the reſpective Places.

HENCE likewiſe it may be diſcovered whether, notwithſtanding the differences obſerved in Gravitation, the primitive Gravity be every where the ſame and tends to a Centre, as Mr. *Huygens* ſuppoſed; or if it is different in different Places, and depends upon the mutual Attraction of the parts of Matter, according to Sir *Iſaac Newton*; whether it varies according to any other Law, and to what points it tends. In fine, the Knowledge of Gravitation towards the Earth, may open the way to that of univerſal *Gravity*, the principal Agent in the Machine of the Univerſe.

CHAP.

CHAP. II.

Experiments made at Pello, *upon the Gravitation of Bodies.*

I.

WE had reſolved to make our Experiments upon Gravitation as near the Pole as poſſible; and for that purpoſe choſe *Pello*, whoſe Latitude is 66° 48′.

THESE Experiments, which elſewhere would be eaſy enough, were in this Country attended with very great difficulties; and without an extraordinary care to maſter them, one ſhould find himſelf very much out in his Reckoning. The great number of Experiments we made, and the great number of Inſtruments we uſed, have taught us what cloſe Attention muſt be had to the ſmalleſt Circumſtance: and if ever any after us ſhall undertake ſuch Experiments, and in ſuch a Country, they will be ſenſible how neceſſary all our Caution was, and how pertinent

tinent the Account is that I am now to give.

'TWAS theſe ſame Difficulties that hindered Mr. *de la Croyere* to make his Experiments at *Kola* and at *Kilduin*, and forced him to give up the Advantages of this Country, for the Convenience of making them at *Archangel*, farther from the Pole. For us, we were ſo many, and ſo well aſſiſted, that we were able to get over a great many Obſtacles, and to purſue our Reſolution of examining the Gravitation of Bodies in the frigid Zone.

AND it is the ſingular Advantage of theſe Experiments, that they were made nearer the Pole than any ever were, without having at all ſuffered in point of Accuracy, either from the Rigor of the Climate, or any other of the Difficulties we had to ſtruggle with.

II.

THE Inſtrument which we uſed for diſcovering the difference of Gravitation at *Pello* and at *Paris*, is a Clock of a particular Conſtruction, invented by Mr. *Graham*, on purpoſe for ſuch Experiments.

THE Pendulum is compoſed of a heavy Bob, of the ordinary Lenticular Form, fitted to a flat Braſs Rod. This Rod is terminated a-top by a piece of Steel perpendicular to it, whoſe Extremities are formed into two Edges, that, inſtead of going between two inclined Planes or two Cylinders, reſt upon two flat pieces of Steel, lying both in the ſame horizontal Plane. The Situation of this Plane is juſt, when the Extremity of the Rod anſwers to the Point o of a Limb, in whoſe Plane the Pendulum moves, and which meaſures the Arcs deſcribed.

THE whole Inſtrument is incloſed in a very ſtrong Caſe; and when it is removed, the Pendulum is ſcrewed up by means of a Frame, ſo as the Steel Edges do not bear on any thing; while the piece of Steel whereof they are formed, is ſupported on either ſide of them.

WITHIN the Box, there is applied a piece of Wood hollowed, to receive the Bob of the Pendulum, and ſo ſecured by another piece that ſhuts over it, that neither the Lens nor the Rod can receive any motion. The only

only liberty the Rod has, is to lengthen and contract itſelf as the Heat or Cold requires; in this reſpect nothing confines it.

THE Lens is 6 inches $10\frac{3}{4}$ lin. in diameter, and its thickneſs at the Centre 2 inches $2\frac{3}{4}$ lin. The Weight that gives motion to the Clock is 11 *lb.* $14\frac{1}{2}$ Ounces, and is wound up once in a Month. And laſt of all, there is fix'd within the Box a Mercurial Thermometer, in which the Point of boiling Water is marked 0, and the Numbers of the Diviſions increaſe with the Cold. Mr. *Graham* ſent us, with this Inſtrument, an Account of the Experiments he had made with it at *London*; wherein he tells us, that when the Thermometer was at 138, the Clock gained upon the *Mean Time* 4′ 4″ in a Day; that when it was at 127, it gained 3′ 58″. And thus a difference of 11 Diviſions in the Thermometer produced the difference of 6″ in the Motion of the Clock.

WITH the ordinary Weight, it deſcribed Arcs of 4° 20′; with half that Weight it deſcribed Arcs of 3° 0′; and theſe great Differences in the Weight and Arcs produced in the going of the Clock,

only a Difference of $3''\frac{1}{2}$ or $4''$ in a day. But ſo much faſter did the Clock go when the ſmaller Arcs were deſcribed.

ONE may ſee from this how little this Clock will be affected by ſmall Differences in the Weights or Arcs, and conſequently by the different Tenacity of the Oil; and how far one may be aſſured, that its Acceleration from one Place to another is the Effect either of an Increaſe of Gravitation, or of the Cold ſhortening the Rod of the Pendulum.

III.

PELLO is a Village of *Finlanders*, as you go up the River of *Torneå*, agreeably enough ſituated upon its Banks. The Art of Maſonry is there abſolutely unknown. Our Lodgings were ſmall Hutts built of Wood, but had nothing of that Solidity which our Experiments required, where there are wanted the very firmeſt Supports.

TOWARDS the end of Summer we had cauſed to be built in one of our Rooms, a great Pillar of hewn Stone; its Thickneſs 6 foot by three; in which we had faſtened ſeveral pieces of Iron to ſupport our Teleſcope

ſcopes and Clocks. To this Wall, which was by this time well dried and ſettled, we fixed a Teleſcope pointed to *Regulus*, very near his Paſſage in the Meridian; and having placed the Clock with all neceſſary Care,

REGULUS paſt by the Vertcial Thread in the Focus.

1737.

The 3d of *April* at $8^h\ 35'\ 13''\frac{1}{4}$ by the
4th . . 8 36 14 [Clock.
5th . . 8 37 8

FROM theſe Obſervations, the Pendulum from the 3d to the 4th, had gained upon the Revolution of the fixt Stars $1'\ \frac{3}{4}''$; and from the 4th to the 5th, $54''$.

IV.

WE were ſenſible that this Inequality in the Clock's Motion proceeded from the different degrees of Heat and Cold; and that, though the Room was as cloſely ſhut as it was poſſible in this Country, yet the different Temperature of the Air would de-

ſtroy all Accuracy in our Experiments. Our only reſource was to keep the Clock always in the ſame degree of Heat. This was no eaſy Undertaking in the midſt of a Cold ſo intenſe, and at the ſame time ſo variable; Day and Night we muſt have our Eyes fixed upon the Thermometers, to increaſe the Fire, or let in the external Air. Yet by extraordinary Patience and Attention we overcame all this; kept the Air to a conſtant Temperature, and made the Clock go with as equal a Motion as can be expected in the moſt favourable Climate. The proof of this was the Experiments themſelves, in which the ſmalleſt Neglect muſt have ſhowed itſelf.

V.

ON the 6th we began to regulate the Fire, by means of two Mercurial Thermometers, which we uſed all along in theſe Experiments, both here and at *Paris*. The one made by the Abbé *Nolet*, after Mr. *de Reaumur*'s Standard; the other by Mr. *Prins*. Theſe Thermometers are differently divided; in the Abbé *Nolet*'s the freezing Point is marked o, and in that of Mr. *Prins* it is marked 32. In either, the Numbers

bers increaſe with the degrees of Heat, and one of the Abbé *Nolet*'s Diviſions is equivalent to very near two of Mr. *Prins*'s. They were placed by the Pendulum, and at the height of the middle of its Rod; and kept continually, for the five days and five nights that theſe Experiments laſted, the Abbé *Nolet*'s between 14 and 15 degrees, and Mr. *Prins*'s between 60 and 62.

IT was of great conſequence that the Thermometers ſhould be placed not only at the ſame diſtance from the Fire as the Pendulum, but likewiſe at the ſame height; for upon lowering them, though at the ſame diſtance from the Fire, the Mercury would fall conſiderably.

THE differences in the length of a Pendulum ariſing from Heat and Cold, are ſo conſiderable with reſpect to thoſe which proceed from the Increaſe of *Gravitation*, that without this Attention to the equal Temperature of the Air, there can never be any tolerable Concluſion drawn from ſuch Experiments.

THE Pendulum deſcribing always Arcs of 4°. 10′. that is, 2°. 5′. on each ſide of the Limb that meaſures them, our Obſervations, after we had regulated the Temperature of the Air, were as follows:

Regulus *paſſed the Thread of the Teleſcope*,

1737.		h	′	″
6th of April . .	at	8	38	1
7th		8	38	54¼
8th		8	39	48½
9th		8	40	42
10th		8	41	35

FROM theſe Obſervations it appears, that from the 6th to the 10th, the Clock had gained 3′. 34″. which gives, for its Acceleration upon one Revolution of the fixt Stars, 53″,5.

CHAP.

CHAP. III.

Obſervations made at Paris *with the ſame Inſtrument.*

AT *Paris*, in the ſame Temperature of the Air, kept up Day and Night by the ſame two Thermometers we had uſed at *Pello*, placed in the ſame manner, the Pendulum ſwinging Arcs of 2°. 10′. on either ſide.

Sirius *paſſed the Thread of the Teleſcope.*

1738.	h	′	″
28th of Febry . . . . at	8	45	40
3d of March . . .	8	45	24
4th	8	45	19
9th . . .	8	44	49
10th	8	44	43
11th	8	44	38
12th	8	44	32½
13th	8	44	27½

WHENCE in 13 Revolutions of the fixt Stars the Pendulum had loſt 1′. 12″,5 which

which gives for one Revolution a Retardation of 5″,6.

CHAP. IV.

Accelerations of the Clock.

I.

Acceleration between Paris *and* Pello.

WE have found (*p.* 216.) that at *Pello*, in one Revolution of the fixt Stars, the Clock gained upon their Motion 53″,5
and that at *Paris* it loſt 5, 6
Whence from *Paris* to *Pello* the Acceleration is 59, 1

II.

Acceleration of the Clock between Paris *and* London.

Mr. *Graham*, upon whoſe Experiments we reckon no leſs than upon our own, had obſerved at *London*, that when the Thermometer contained in the Caſe of the Clock ſtood at 127, the Clock gained upon the

Mean

Mean Time 3′, 58″. in a day, that is, 2″,1 upon one Revolution of the fixt Stars. Now this Diviſion 127 of his Thermometer anſwering to 14½ and 61 of theſe two which we uſed both at *Pello* and at *Paris*, it is plain the Experiments at *London* and at *Paris* were made in an Air of the ſame Temperature. The Oſcillations were likewiſe the ſame, *viz.* 2°. 10″. on either ſide of the Perpendicular. Whence the Clock having, at *London*, gain'd upon one Revolution of the fixt Stars . . . . . 2″,1
and at *Paris* having loſt . . . 5, 6
the Acceleration from *Paris* to *London* in one Revolution, is 7, 7

CHAP. V.

Experiments made with other Inſtruments.

WE had another Inſtrument, excellent for theſe Purpoſes; a Clock of Mr. *Julian le Roy*, which, in all the Trials we made, was found to go admirably well.

ALL

ALL this Country being, as it were, one Maſs of Iron and Loadſtone, we apprehended the effects of ſome Magnetiſm in uſing this Clock, whoſe Rod was of Steel. We likewiſe wanted to make ſome Experiments with Pendulums of different ſpecific Gravities. Mr. *Camus*, who joins to his other Accompliſhments a perfect Skill in Mechanics, ſupplied alone whatever we could want in a Country that knows no other Arts but Fiſhing and Hunting. He formed upon a Turn, five perfect Globes of two Inches $4\frac{1}{2}$ lin. diameter, of as many different Metals which he had melted down. Each Globe was paſt through with a Braſs Rod, which was eaſily fixt to the extremity of another of the ſame Metal; this laſt having been firſt fitted to the Clock.

IT was in the time of our moſt accurate Experiments at *Pello*, the 6, 7, 8, 9 and 10th of *April*, when the Air was kept Night and Day in the ſame degree of Heat, that we made the Compariſon of the two Clocks, Mr. *Graham*'s and Mr. *le Roy*'s. We made this laſt go 12 Hours with each of the five Globes, charging the Weight that gives the Motion

Motion with as many leaden Bullets as made the Vibrations always of 3°. 55′. on each ſide. A Circumſtance which we likewiſe obſerved at *Paris*.

THE Motion of this Clock, with the five different Globes, at *Pello* and at *Paris*, and in the ſame degree of Heat, was as follows:

In 12 *Hours, by Mr.* Graham's *Clock.*

	At *Pello.*	At *Paris.*
	′ ″	′ ″
The Globe of Lead loſt . .	9 14⅓	. . 9 14
The Globe of Silver loſt .	8 42	. . 8 44
The Globe of Iron loſt . .	5 29	. . 5 29½
The Globe of Tin loſt . .	6 6	. . 6 8
The Globe of Copper loſt	6 48	. . 6 50

THE difference of 2″ which three of theſe Globes give between the Motion of the Clock at *Pello* and here, is not conſiderable. It may probably have been occaſioned by the manner in which the Rods of the Globes were fitted to the Clock. If the extremities of the Rods to which the Globes were fixed, miſs'd ever ſo little to riſe to the ſame point of the Rod that was common

mon to them all, ſome ſmall difference in the lengths muſt happen. And how ſmall indeed is ſufficient to produce a difference of 2″! This, however, muſt always be a Source of ſome little Error in Experiments made with Clocks, whoſe Pendulums are taken off, when they are carried from one place to another.

HENCE we may ſee how proper good Clocks are for diſcovering the Increaſe or Decreaſe of Gravitation. And if it had not been actually verified, no body could ever have believed, that in theſe Experiments two Clocks of ſuch different Conſtruction as Mr. *Graham*'s and Mr. *le Roy*'s are, ſhould ſo accurately correſpond. In Mr. *le Roy*'s, the Rod of the Pendulum was fixt to two Springs, which might be ſuſpected to have different Elaſticities: The Globes differed widely from Mr. *Graham*'s Lens, in Weight as well as Shape; and the Arc which they deſcribed was almoſt double to that of the Lens.

WE ſhall ſay nothing of ſome other Experiments which give the Increaſe of Gravitation at *Pello* ſtill greater than we found

found it by Mr. *Graham* and Mr. *le Roy*'s Clocks, becauſe the Inſtruments with which they were made, are ſo inferior to theſe Clocks that they ought not to be ſo much as compared with them.

CHAP. VI.

Reflections upon the Increaſe of Gravitation.

I.

Compariſon of the Increaſe of Gravitation between Paris *and* Pello, *with the ſame as deduced from Sir* Iſaac Newton*'s Table.*

THE Acceleration from *Paris* to *Pello*, found as above, is greater by 6″,8 than Sir *Iſaac Newton*'s Table makes it, (*lib.* 3. *Phil. Nat. Princ. Math.*) and conſequently, according to his Theory, the Earth is *flatter* than he determines it to be.

II. *Com-*

II.

Compariſon of the Increaſe of Gravitation between Paris *and* Pello, *with what reſults from the Experiments made at* Jamaica.

FROM Mr. *Campbell*'s Experiments at *Jamaica* made with one of Mr. *Graham*'s Clocks, Mr. *Bradley* has calculated another Table, (*Phil. Tranſ.* N°. 432.), upon the Principle employed by Sir *Iſaac Newton* and Mr. *Huygens*, that Gravitation increaſes towards the Pole as the Square of the Sine of the Latitude; and the Acceleration from *Paris* to *Pello*, as deduced from this Table, exceeds what we found it to be, by 4″,5.

III.

Compariſon of the Increaſe of Gravitation with what reſults from Mr. Huygens's *Theory.*

IN fine, All the Experiments which the Academicians, ſent by the KING to *Peru*, have made, either at *S. Domingo* or the *Equator*, conſpire with ours, to make the Increaſe of Gravitation towards the Pole, greater than according to Sir *Iſaac Newton*'s

Newton's Table, and by conſequence the Earth flatter than he has made it. And all of them fall ſo wide of Mr. *Huygens*'s Theory (*Diſcours de la cauſe de la Peſanteur*) which makes it ſtill leſs, that his Theory muſt itſelf be wide of the Truth.

IV.

Compariſon of the Increaſe of Gravitation between Paris *and* Pello, *with that between* Paris *and* London.

THE Acceleration from *Paris* to *Pello* being 59″,1. that from *Paris* to *London* ought to be 9″,8. and we found it above, to be 7″,7. Whether this difference is real, or if it is owing to ſome Error in our Experiments, I leave others to judge. And if this laſt is the caſe, how exquiſite muſt that Inſtrument be, which, tranſported from *London* to *Pello*, from *Pello* to *Paris*, and tried in theſe three places, is found to agree ſo accurately with itſelf?

V.

Compariſon of the Gravitation of Bodies at Paris *to that at* Pello.

THE Gravitation of Bodies at *Paris* is to that at *Pello*, as the Square of the Number of Oſcillations of a Pendulum at *Paris* in one Revolution of the fixt Stars, is to the Square of the Number of Oſcillations at *Pello* in the ſame time, that is, as 10000 to 10014.

VI.

Length of the Pendulum that ſwings Seconds at Pello.

TO find the Length of a Pendulum that ſwings Seconds at *Pello*, you have only to compare the Squares of the Number of Oſcillations made in the ſame time at *Pello*, and at *Paris*, with the length of a Pendulum at *Pello*, and that of a Pendulum at *Paris*; which laſt Mr. *de Mairan*, has, by repeated and unqueſtionable Experiments, found to be 440,57 Lines. And you will find the length of a Second-Pendulum at *Pello* to be 441,17 Lines.

FOL-

FOLLOWS a *Table*, which I have calculated, upon the Increaſe of Gravitation between *Paris* and *Pello* as above determined; and upon this Principle, That Gravitation increaſes from the Equator to the Pole, very nearly in the Ratio of the Squares of the Sines of Latitude. In this Table, the Augments of Gravitation are expreſſed two different ways; by the *Accelerations* of a Clock in a Revolution of the fixt Stars, and by the *Lengthenings* of a Pendulum that ſwings Seconds from the Equator to the Pole.

TABLE

Of the Accelerations of a CLOCK, and of the Lengthenings of a PENDULUM *from the Equator to the Pole.*

LATITUDE of the Place.	ACCELERATION in one Revolution of the fixt Stars.	FRACTIONS of a Line, and Lines by which the Pendulum is to be lengthened.
0°	0″	0
5	1,6	0,016
10	6,4	0,065
15	14,3	0,145
20	24,9	0,254
25	38,1	0,387
30	53,3	0,542
35	70,2	0,713
40	88,1	0,896
45	106,6	1,084
50	125,1	1,273
55	143,1	1,455
60	159,9	1,626
65	175,1	1,781
70	188,3	1,915
75	198,9	2,023
80	206,8	2,103
85	211,6	2,152
90	213,2	2,169

CHAP.

CHAP. VII.

A Method for finding the Direction of Gravity.

PROBLEM.

The Figure of the Earth being given, as also the Proportion of Gravitation at the Equator to that of any given Latitude; To find the Angle which the Direction of the actual Gravitation makes with the Direction of the primitive Gravity, or that Point of the Earth's Axis to which Gravity tends.

LET the Spheroid $APap$ represent the Earth, whose Axis is Pp, and the Diameter of the Equator Aa. Let the Gravity in A, that is, at the Equator, be represented by AG; and the centrifugal Force by $A\mathfrak{Q}$; then will the Gravitation there be represented by AH, the difference of AG and GH (or of AG and $A\mathfrak{Q}$.) Fig. 18.

IN

IN any other place of the Earth D, let the Gravitation be expreſs'd by $D\,T$. And by the Laws of Hydroſtatics, ſeeing the Direction of Gravitation is always perpendicular to the Surface of the Earth, $D\,T$ will be perpendicular to a Line touching the Spheroid in D.

IF upon $F\,D$ continued, there be taken $D\,Z = \frac{D\,F \times A\,Q}{A\,C}$, $D\,Z$ will repreſent the centrifugal Force in D, and its Direction will be that of $D\,Z$.

DRAWING then from the Point T, the Lines $T\,N$, $T\,S$ perpendicular to the Axis, and forming the Rectangle $D\,N\,T\,S$, the Gravitation will be reſolved into two Forces, one acting in the Direction $D\,S$, which is not affected by the centrifugal Force; and the other acting in the Direction $D\,F$, which has been diminiſhed by it.

THE centrifugal Force has taken from this laſt the Quantity $D\,Z = \frac{D\,F \times A\,Q}{A\,C}$, which

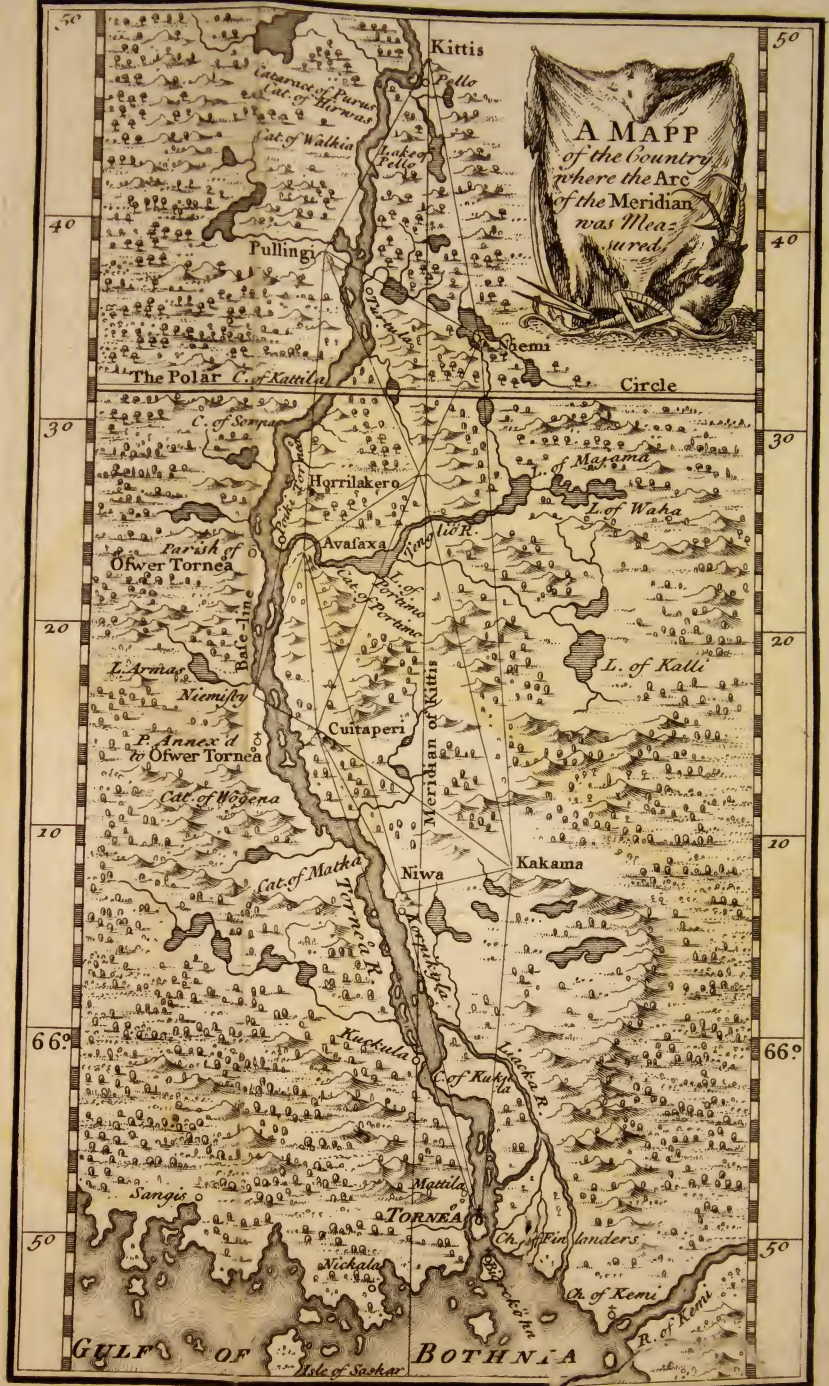
which must be restored to the Force in the Direction $D F$, in order to find the whole Force of primitive Gravitation in the Direction $D F$. Taking therefore $NV = DZ$, and, through V, drawing VO parallel to the Axis, the Lines VO, SO will represent the Forces which result from Gravity. The Diagonal DO, the quantity of Gravity itself, and the little Angle ODT will be that of the two Directions of Gravity and Gravitation.

THE centrifugal Force at the Equator being $\frac{1}{288}$ of the Gravitation, we have $AQ = \frac{1}{288} AH$, and $DZ = \frac{DF \times AH}{288\, AC} = TO$. Having drawn from a Point infinitely near D, the Line dM parallel to DE, and from the Point T, the Line Tt perpendicular to DO, we shall have by similar Triangles $Dd : Md :: TO : Tt$, or $Dd : Md :: \frac{DF \times AH}{288\, AC} : Tt = \frac{Md \times DF \times AH}{288 \times Dd \times AC}$, the Sine of the Angle TDO to the Radius DT. Whence we have the Equation $\frac{Tt}{DT} = \frac{Md \times DF \times AH}{288 \times Dd \times AC \times DT}$.

THIS

THIS Formula contains the Angle of the two Directions of Gravity and Gravitation; the Latitude of the Place expreſs'd by $\frac{M\,d}{D\,d}$; the Radius of the Equator, and the Radius of the Parallel under which the Experiments are made; with the Ratio of Gravitation at that Place to Gravitation at the Equator. Whence different Theorems may be deduced, for different Suppoſitions of the known Quantities.

THE END.



W. H. Toms Sculp.

I.

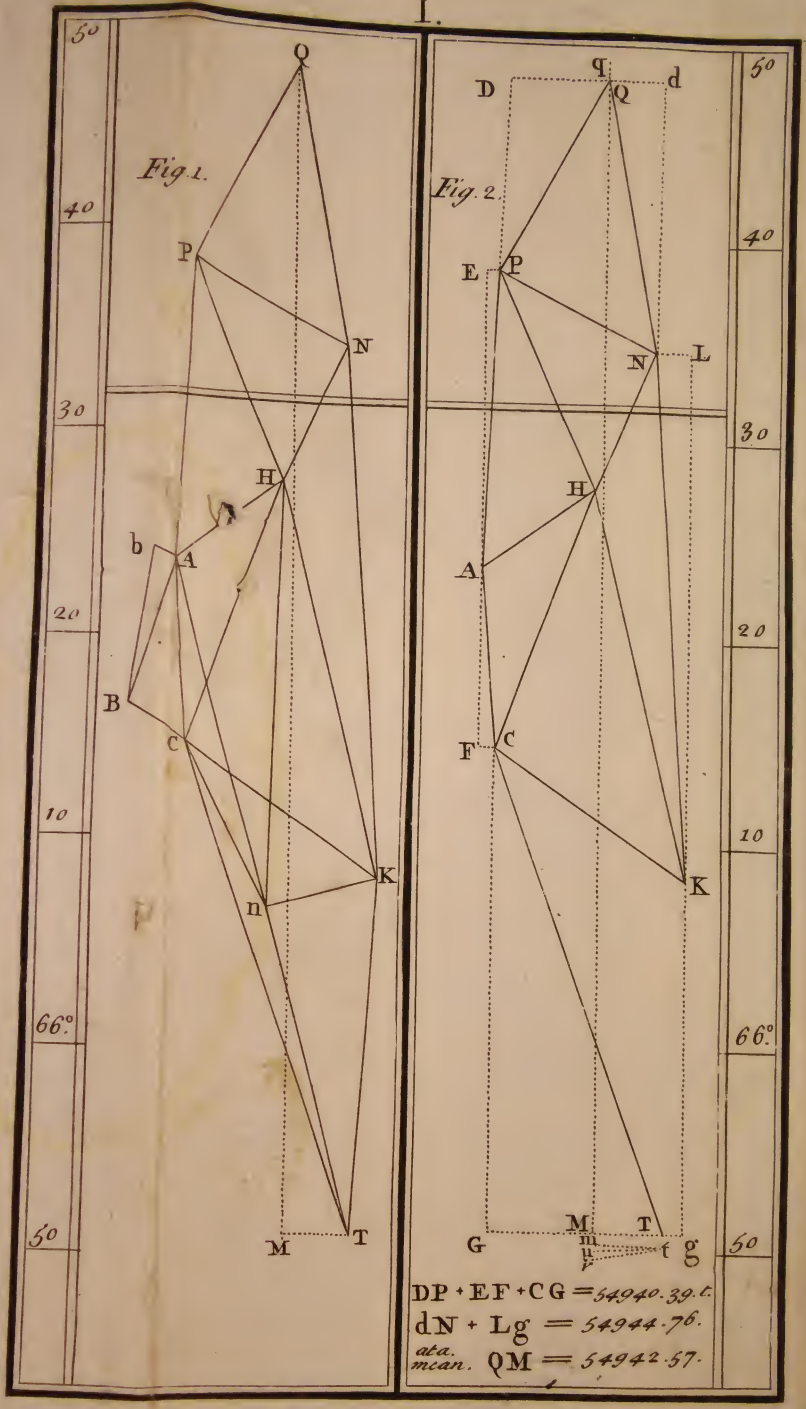
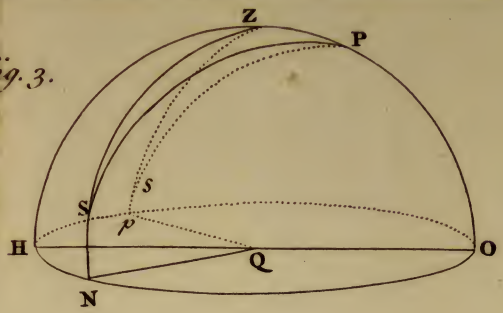


Fig. 1.
Fig. 2.
50
40
30
20
10
66°
50
Q
P
N
H
b
A
B
C
K
n
M
T
q
D
Q
d
E
P
N
L
H
A
F
C
K
G
M
T
m
n
f
g
DP + EF + CG = 54940.39. c.
dN + Lg = 54944.76.
ata. mean. QM = 54942.57.

Fig. 3.



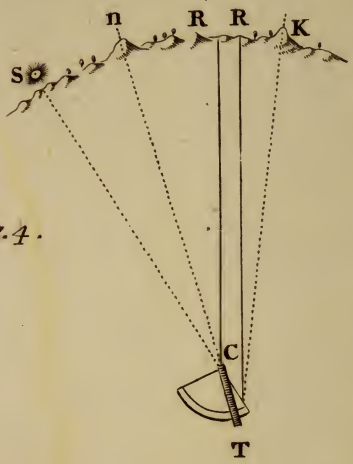


Fig. 4.

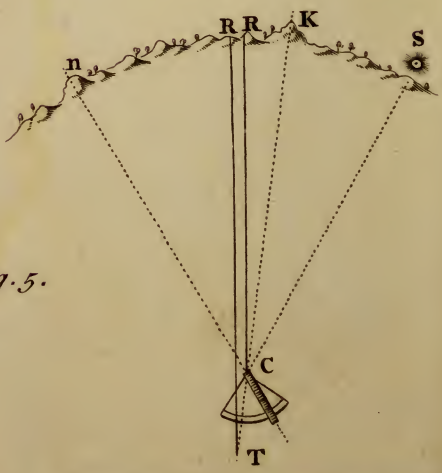


Fig. 5.

III.

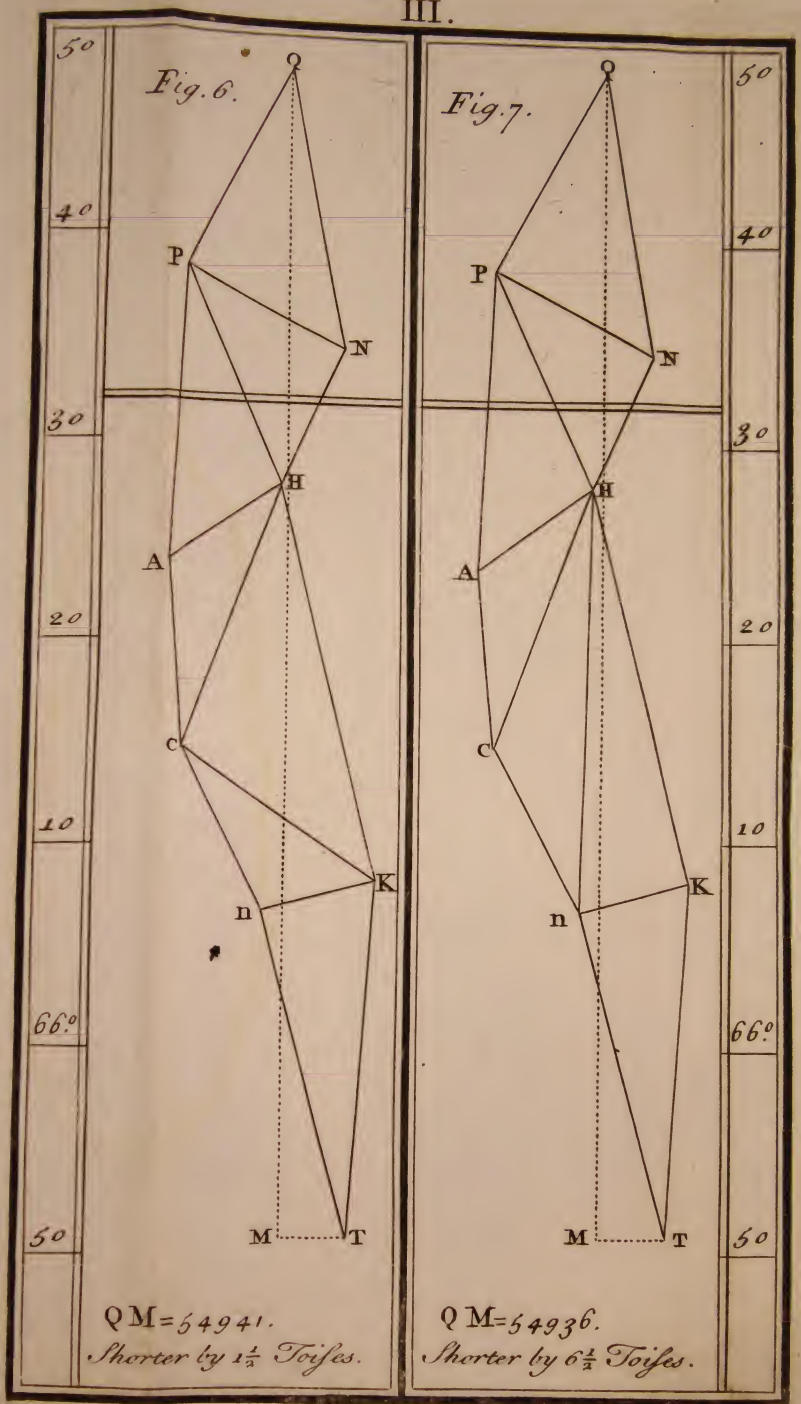
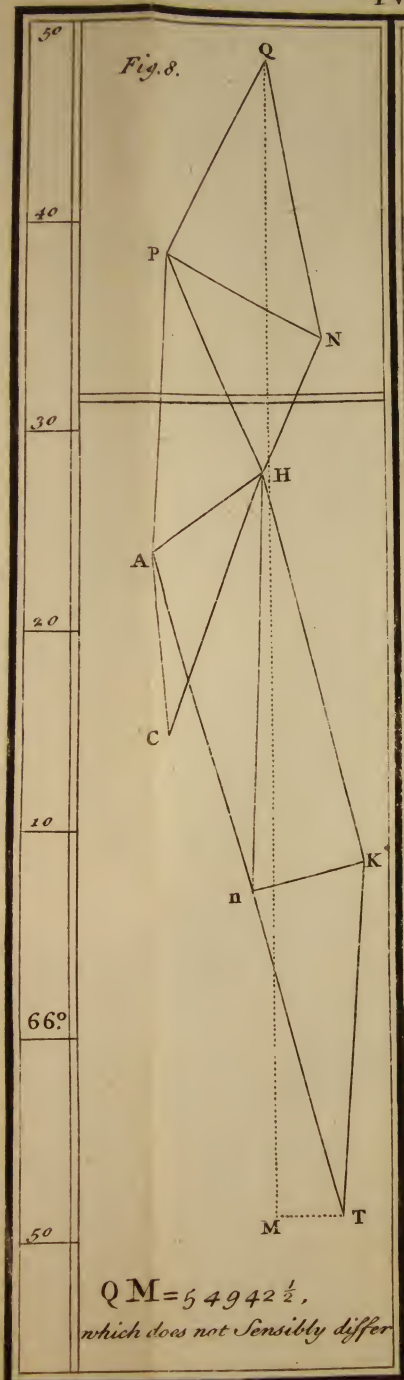
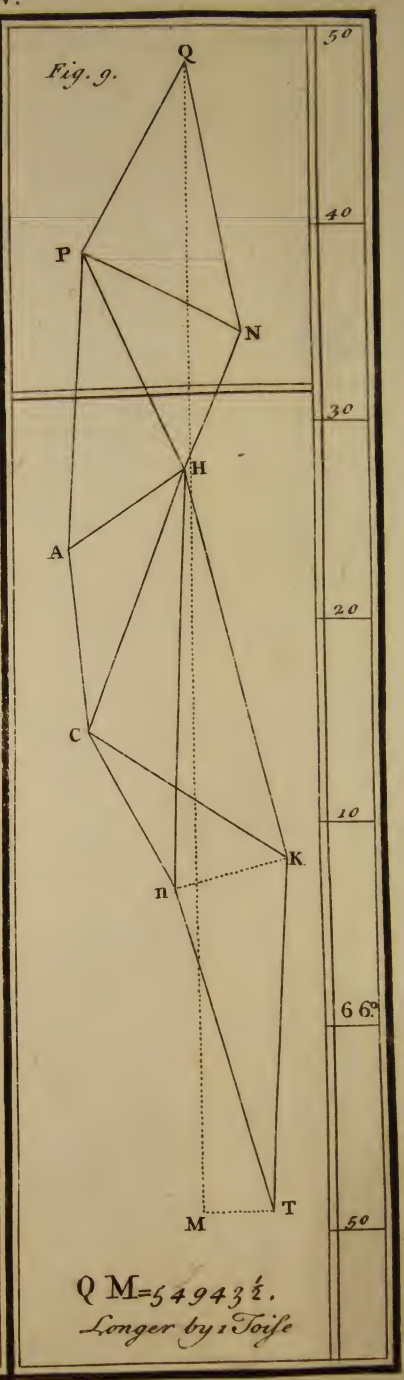


Fig. 6.
Fig. 7.
50
40
30
20
10
66.º
50
P
N
H
A
C
K
n
M
T
Q M = 54941.
Shorter by 1¼ Toises.
Q M = 54936.
Shorter by 6¼ Toises.

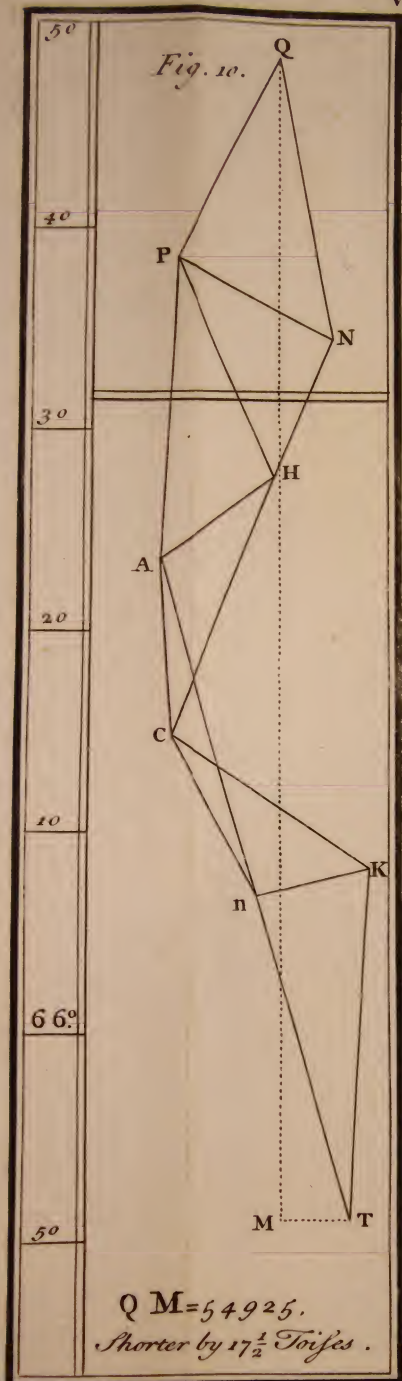


Q M = 5 4 9 4 2 ½,
which does not Sensibly differ

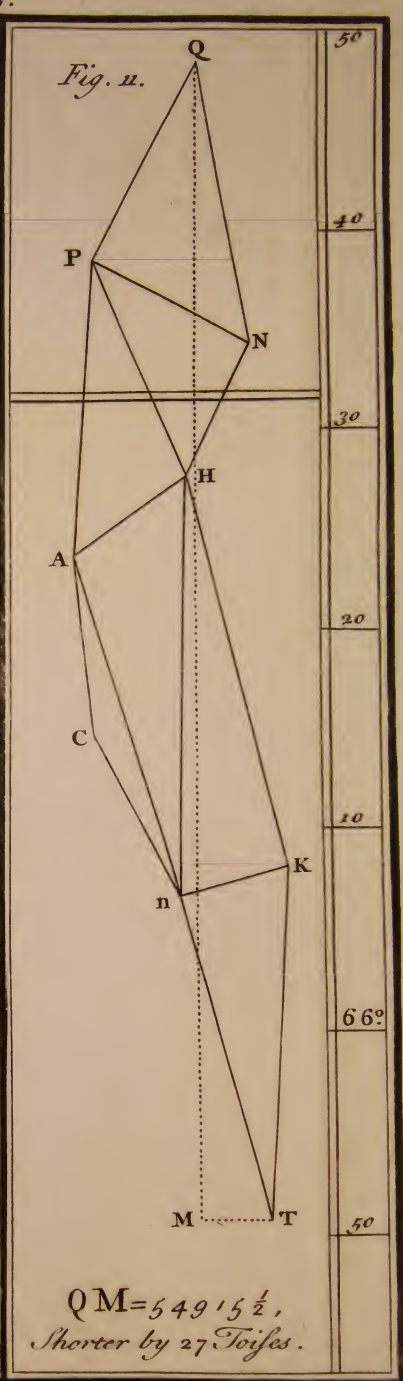


Q M = 5 4 9 4 3 ½.
Longer by 1 Toise

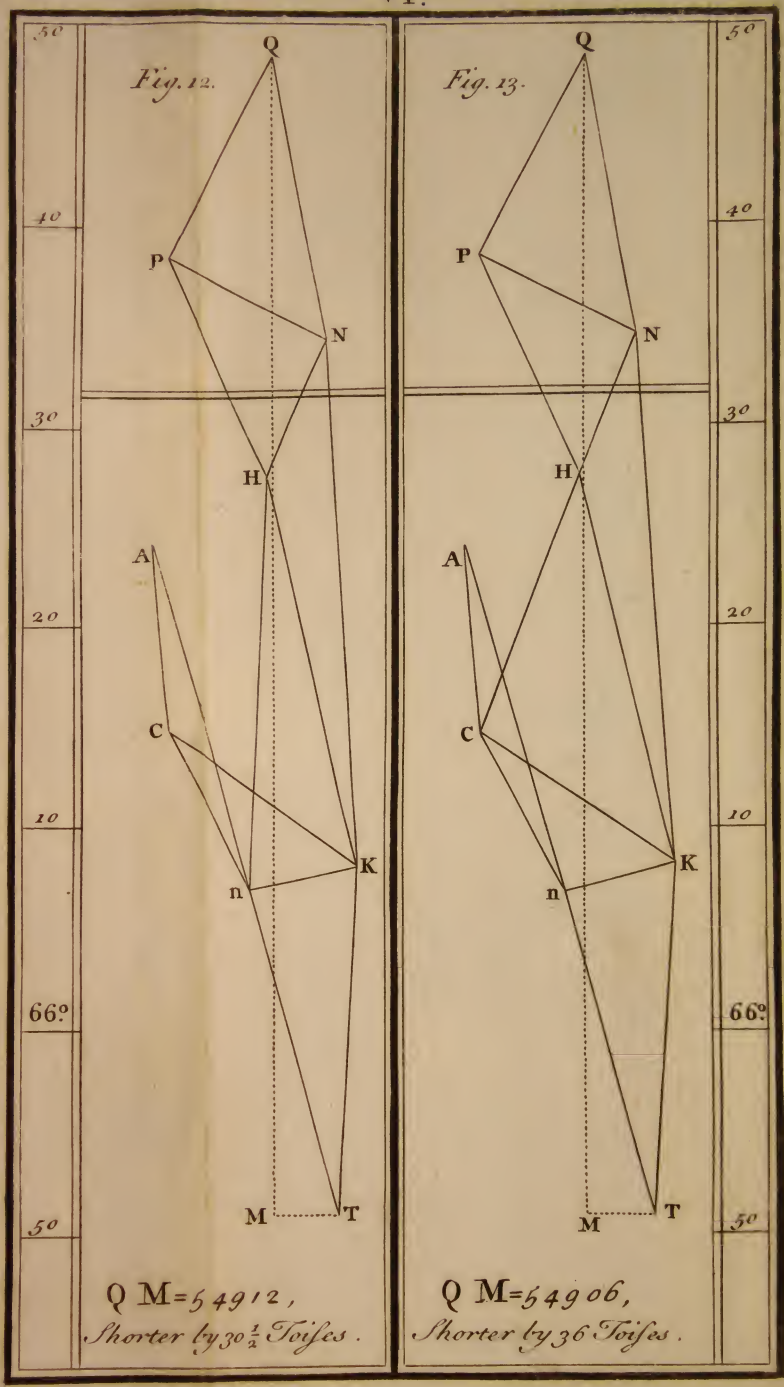
V.



Q M = 54925.
Shorter by $17\frac{1}{2}$ *Toises.*



Q M = 54915 $\frac{1}{2}$,
Shorter by 27 *Toises.*


50
40
30
20
10
66º
50
Fig. 12.
Q
P
N
H
A
C
K
n
M
T
Q M = 54912,
Shorter by 30 1/2 Toises.
Fig. 13.
Q
P
N
H
A
C
K
n
M
T
Q M = 54906,
Shorter by 36 Toises.

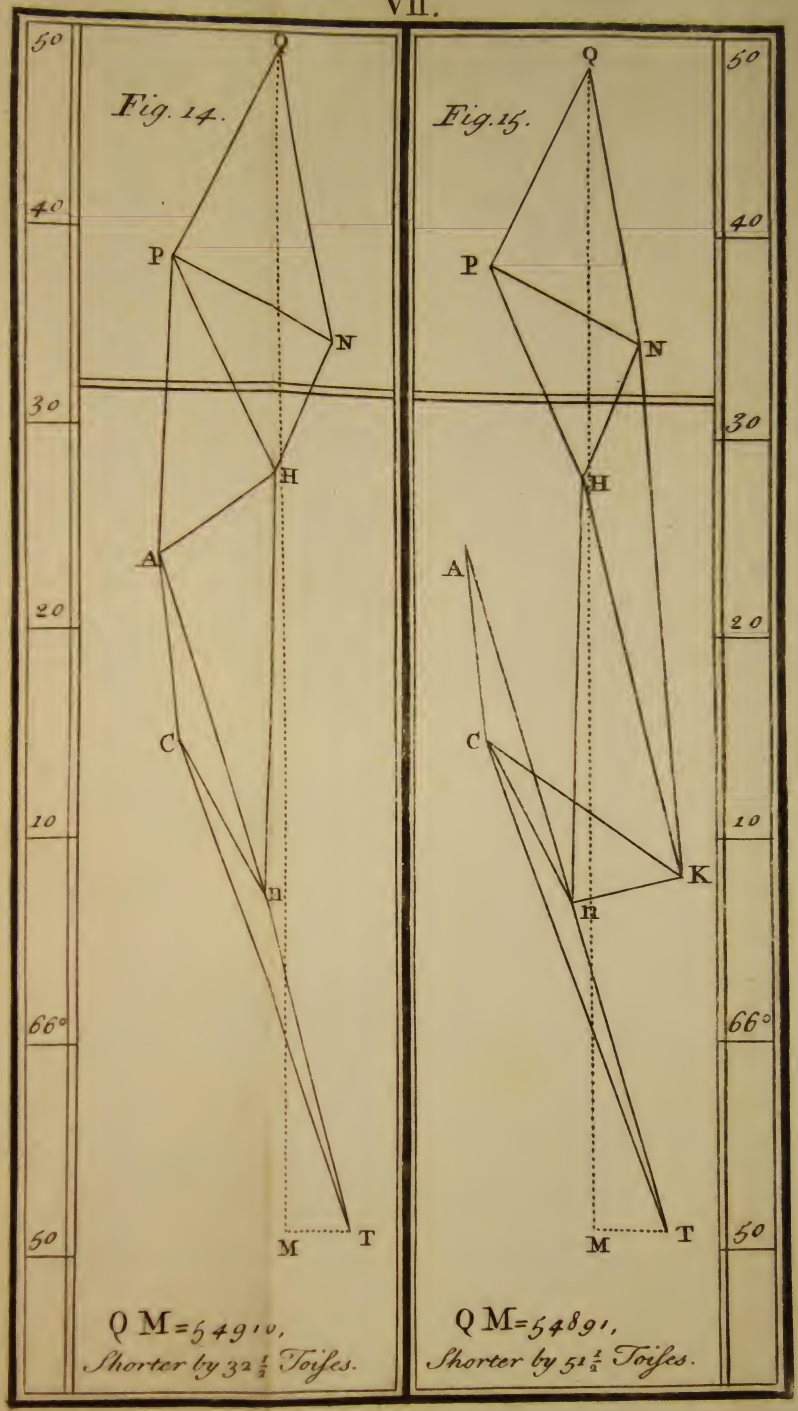


Fig. 14.
Q
P
N
H
A
C
n
M
T
50
40
30
20
10
66°
50
Q M = 54910,
Shorter by 32 1/2 Toises.
Fig. 15.
Q
P
N
H
A
C
K
n
M
T
50
40
30
20
10
66°
50
Q M = 54891,
Shorter by 51 1/2 Toises.

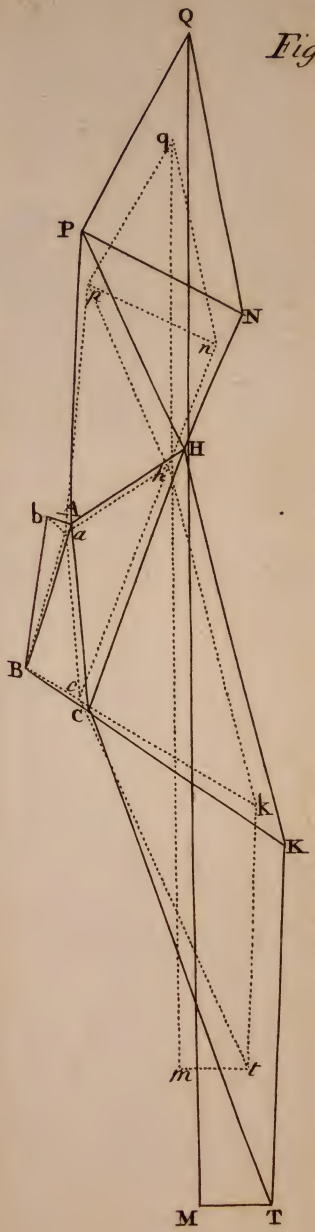


Fig. 16.

qm = 54886 Toises, Shorter than Q M *by 54 Toises.*

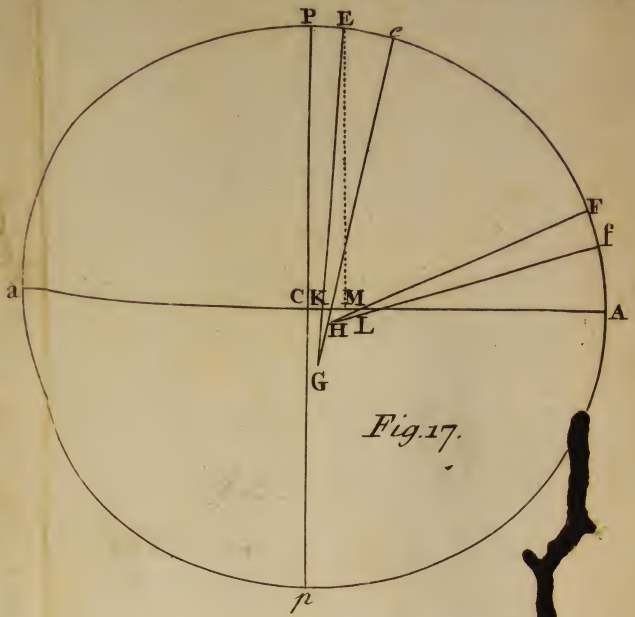


Fig. 17.

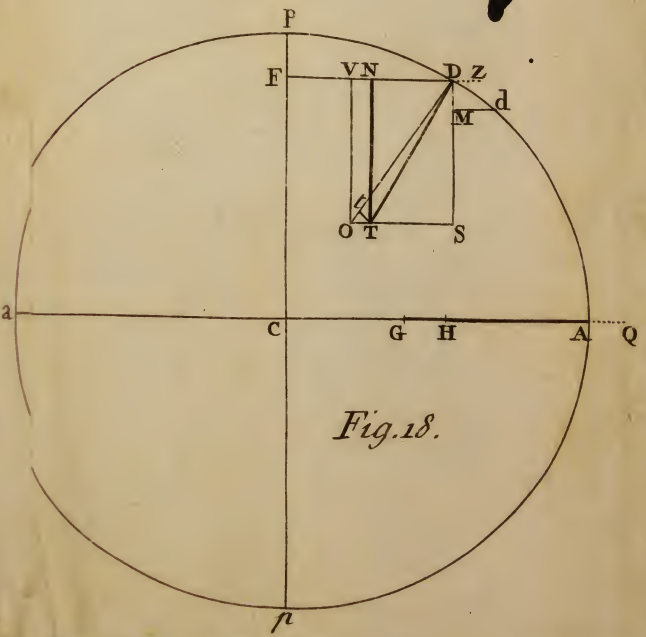


Fig. 18.